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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

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The original Russian articles are translated by competent technical personnel. The translations are on a cover-to-cover basis and the Instrument Society of America and its translators propose to translate faithfully all of the scientific material in *Izmeritel'naya Tekhnika*, permitting readers to appraise for themselves the scope, status, and importance of the Soviet work. All views expressed in the translated material are intended to be those of the original authors and not those of the translators nor the Instrument Society of America.

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Transliteration of the names of Russian authors follows the system known as the British Standard. This system has recently achieved wide adoption in the United Kingdom, and is currently being adopted by a large number of scientific journals in the United States.

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Measurement Techniques

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(Russian Original Dated January, 1961)

1961, No. 1, pp. 1-90 September, 1961

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IMPORTANT TASKS IN THE DEVELOPMENT OF METROLOGICAL WORK

G. D. Burdun

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 1-2, January, 1961

Having successfully completed the second year of the Seven-Year Plan, the Soviet people are confidently advancing on the road of communist construction.

At the end of 1960 the USSR Supreme Soviet Session approved the national economic plan and state budget for 1961, the third year of the Seven-Year Plan for the development of the USSR national economy. It was decided, among other things, to raise in 1961 the production of instruments and automation equipment by 21%.

The important tasks assigned to the USSR industry by the decisions of the CPSU 21st Congress, and the June (1959) and July (1960) plenary sessions of the CPSU Central Committee on technical progress, assimilation of new techniques, production automation and mechanization, place new and more exacting requirements on the development of metrological work in our country. This work must be up to the level of modern science, technology and the tasks of the Seven-Year Plan.

It is necessary to continue spreading in all the branches of science, national economy and teaching the unified system of units "meter, kilogram, second, ampere, degree Kelvin, candle," which has been designated as the preferred system by new state standards on measuring units. The Ninth General Conference on Weights and Measures adopted in October 1960 this system of units as an International System and the International Committee of Legislative Metrology recommended its adoption by legislation by the member states of the organization.

The problem of raising the accuracy of standards is of outstanding importance. The present development of radio technology, atomic energy, rocket technology, and automation requires the raising by at least one order of accuracy the standard units of length, time, electrical resistance, etc.

It is necessary to adopt in practice the new determination of the meter by means of light wavelengths, and to use on a wider scale interferometer methods for precise measurements, thus raising the accuracy of linear measurements by a factor of 10-20.

A wide application of molecular and atomic standards in the state time and frequency services should raise by at least one order the accuracy of the frequency and precise time signals transmitted by radio.

The D. I. Mendeleev All-Union Scientific Research Institute of Metrology should speed up its work on raising the stability of standard and reference resistors, and catch up with its schedule. The work on establishing new electrical standards on the basis of nuclear phenomena should be developed on a wide scale.

The metrological institutes of the Committee of Standards, Measures and Measuring Instruments are carrying out important work in establishing methods of accurate measurements, reference instruments and equipment. Here the most important task is the development of precision measurements and a corresponding reference measuring equipment for such spheres as physicochemical measurements of the properties of matter, measurements of ionizing radiations, and other spheres of new technology, as well as the extension of precision measurements to very large and very small quantities (in the sphere of large forces, ultrahigh pressures and high vaccum, large currents and high voltages, high and ultrahigh frequencies, extremely low and high temperatures, etc.).

The metrological institutes are faced with the tasks of applying the results of scientific research work both in our national economy and in developing the activity of state inspection laboratories of measuring equipment.

The development of instrument-making in the Soviet Union, as set out in the Seven-Year Plan, places before the basic organizations in various branches of instrument making and metrology important tasks for a further extension and improvement of standardization in instrument making and of state testing of measuring instruments.

The Committee of Standards, Measures and Measuring Instruments has approved the state plan for standardization in 1961, which provides for further development of standardization in instrument making.

According to existing legislation all measuring instruments must pass state tests before being placed on the market. From April 1, 1960 new regulations for state testing (regulations 2-59) become effective. Their application should considerably improve state testing. The procedure specified in these regulations should be applied strictly, especially with respect to testing experimental models of measures and measuring instruments, and as many interested organizations as possible should be drawn into participating in these tests.

Important and responsible tasks face the local agencies of the Committee in strengthening their supervision of instrument making, withdrawing from production obsolete instruments and replacing them by new measuring instruments. In this respect a good example has been set by the state inspection laboratories of the Ukrainian and Estonian SSR as well as by the Department of State Inspection and Standardization of the D. I. Mendeleev All-Union Scientific Research Institute of Metrology.

The largest volume in the metrological work of the Committee's local agencies consists of the state inspection of measuring equipment, checking of the reference measures and measuring instruments in current use, and assisting plants to introduce new, modern measuring methods and equipment.

In the first half of 1960 alone the state inspection laboratories checked over 40 million measures and measuring instruments in current use and those ready to be placed on the market by the instrument-making industry.

From January 1, 1960 new regulations for state inspection of measures and measuring instruments (regulations 12-58) have been introduced in the USSR. They provide basic specifications for state and service inspection of measuring equipment and introduce a number of improvements in the methods of checking measures and measuring instruments.

The state inspection laboratories and service inspection agencies must ensure uniformity and accuracy of measures and measuring instruments, check their correct utilization, introduce new measuring equipment, assist in organizing repairs and adjustment of instruments, and ensure an efficient condition of the measuring equipment in the areas of their operation.

The increasingly important part played by metrological work in various spheres of science and technology requires the extension of that work. An appropriate place should be allocated in the work of the scientific research institutes of the USSR Academy of Sciences to the development of new measuring methods for a number of scientific investigations and the development of scientific instrument making required in such investigations. The development of scientific instrument making is one of the essential conditions for the further progress of our country.

In view of the ever-increasing part played by instruments used in agriculture, it is important to develop measuring equipment for various branches of agricultural production.

In order to fulfill the tasks connected with the technical progress in instrument making and the application of automation in our economy, the scientific research institutes in the instrument-making industry should apply on a wide scale the modern achievements in electronics, radio isotopes, ultrasonics, etc., for the development of new instruments and means of automation.

The part played by factory laboratories is greatly enhanced. They should become focal points for introducing new measurement equipment in the plants. The new standard regulations on factory laboratories approved by the Committee of Standards, Measures and Measuring Instruments provide for the reorganization of the work of these laboratories in that respect.

The volume of work of the service inspection agencies of measures and measuring instruments has been greatly increased. Their functions should be considerably extended with respect to checking and ensuring the

accuracy and efficient utilization of measuring instruments, assimilation of improved measuring equipment and methods for testing the quality of production, checking the technological processes, and organizing the repair of instruments.

In 1960 a number of metrological institutes and state inspection laboratories organized conferences of the readers of "Measurement Techniques," at which suggestions were accepted and recommendations made for the improvement of the journal, with the object of raising the level of Soviet metrology and measurement techniques. In starting its publication in the New Year the journal will strive to assist in every way the attainment of this objective, which is based on the requirements of the Seven-Year Plan for the development of the national economy of the USSR.

RAISING THE ACTIVITY OF FACTORY TEST LABORATORIES*

M. T. Markin

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 3-4,
January, 1961

One of the causes which hamper the further development and strengthening of the activity of factory test laboratories is the form of their organization. The majority of factories have separate laboratories for each type of measurement, subordinated to various departments in the plant, instead of having a single agency supervising all the measurements. Such isolated test laboratories, which often lack qualified metrological experts, are restricted in their activity and cannot carry out efficiently the tasks assigned to them.

It often happens that in factories with efficient and well equipped laboratories engaged in certain types of measurements and subordinated to different departments, other spheres of measurement remain without supervision, although with an efficient organization it would have been possible to have established supervision over all the measuring and automatic testing equipment.

In order to provide a strong encouragement for the factory test laboratories to participate in the technical development of our country, the Committee of Standards, Measures and Measuring Instruments has worked out and approved on November 4, 1960, a model instruction on central test laboratories for measuring equipment in factories. This instruction has also been approved by the majority of State Planning Committees and State Scientific and Technical Committees of the Union Republics, Councils of National Economy, and by those establishments which were requested to comment on the draft instruction.

The main features of this instruction are:

1. the unification of all the test laboratories and workshops repairing measuring equipment existing in a plant into a single central test laboratory subordinated to the Chief Engineer of the plant;

2. strengthening the factory test laboratories by qualified personnel;

3. encouraging the participation of factory test laboratories in the work of the production departments in introducing production automation, improving the existing methods of measuring physical quantities and parameters, assimilating in production new measuring techniques, as well as in discovering and eliminating the causes for rejects in production and other production losses due to imperfect or inaccurate measuring equipment.

The model instruction lays down that the test laboratory for measuring equipment is an independent entity subordinated to the Chief Engineer of the plant, and enjoys the same rights as a department or a workshop, depending on the scale of production and the number and variety of measuring and automatic testing instruments

* The present article, which describes the basic routine regulations on factory central laboratories for measurement equipment, summarizes the discussion conducted on the pages of this journal in 1959-1960 on the problem of the activity of factory test laboratories.

in current use. The central laboratory may comprise laboratories or sections, and control and checking stations for various types of measurements, groups for developing and introducing new measuring and automatic testing equipment, repair and experimental workshops for assembling, repairing and adjusting measures, measuring and automatic testing equipment of the plant, and for carrying out experimental work in the sphere of measurements.

The instruction stipulates that if the volume of work is sufficiently large certain laboratories and groups of the central laboratory may be organized as independent units; if the volume of work for certain types of measurements is small, the corresponding laboratories, sections or control and checking stations are not set up within the central laboratory, and the inspection of the corresponding measuring equipment of the plant is carried out by contract with the area laboratories of the Council of National Economy (Ministry), or other specialized organizations which have the required testing permit, or else by dispatching the measures and measuring instruments to the local agencies of the Committee for inspection.

The model instruction stipulates that the basic task of a central laboratory for measuring equipment consists in promoting a high quality of industrial production by maintaining the measuring equipment at an up-to-date level of development, ensuring its accuracy and efficient use, developing and constantly improving methods of testing and controlling production.

In conformity with this basic task, the model instruction stipulates that the factory central test laboratory should, in addition to its inspection functions for providing uniformity, accuracy and correct use of measuring equipment, also be entrusted with the following work:

a) ensuring that the measuring equipment and methods at the plant meet the accuracy requirements established by state standards, the technical conditions, and production instructions which specify technological processes, quality of materials, semi-finished products and articles, packing and delivery of products, keeping a check on equipment and materials, etc.;

b) systematically studying in all the factory departments the current measuring methods in order to improve them and introduce them in production;

c) participating in the work of production departments related to the choice of measuring equipment, control of technological processes, of the quality of components and articles, and with the preparation of instructions for the development of measuring equipment required by the plant;

d) participating in the work of the factory technological agencies in production automation related to measuring equipment, both in preparing and planning this work and in installing, adjusting,testing and current use of the appropriate measuring equipment;

e) studying the operational properties of measures, measuring and automatic testing instruments produced by our industry, summarizing the result of this work and making suggestions to the producer plants on the improvement of their quality; working out methods for raising the life of the measuring equipment and replacing obsolete equipment with up-to-date measuring and automatic testing instruments;

f) checking the installation of measuring and automatic testing equipment in order to ensure the required accuracy and reliability in its operation;

g) participating in the work of the technical control divisions and factory technological agencies in discovering the causes of rejects and other losses in production due to imperfect or inaccurate measuring equipment, as well as in working out and introducing measures for eliminating and preventing such losses.

The model instruction stipulates that all the work connected with maintaining the measuring equipment at an up-to-date level of development, ensuring the uniformity and accuracy of measures and measuring instruments, and of improving the measuring equipment inspection methods at the plant must be carried out on the basis of plans worked out yearly by the central test laboratories in conjunction with other factory departments (chief technologist, chief designer, chief power engineer, etc.), and approved by the Chief Engineer.

In order to raise the standard of factory test laboratories the model instruction stipulates that the personnel of these laboratories must possess the following educational and other qualifications:

a) the head of the factory central test laboratory (chief metrologist of the plant), and the leader of the group for developing new measuring and automatic test equipment must have higher technical education and practical experience in measurement technology and automation;

b) heads of test laboratories (sections), the head of the repair and experimental workshop, senior and junior engineers must have either higher or secondary technical education and practical experience in the sphere of measuring technology and automation;

c) senior laboratory assistants (senior inspectors) must have secondary technical education with subsequent study at special courses for measurement technology and practical experience in a specified branch;

d) laboratory assistants (inspectors) must have a full secondary education with subsequent study at special courses or apprenticeship in measurement technology;

e) mechanics for repairing measuring and automatic testing instruments should have the qualifications specified by the unified rate and handbook qualifications.

In a supplement to the model instruction requirements for the premises and installation of equipment in test laboratories are specified.

Having examined these documents the Committee resolved:

To send a copy of the model instruction on factory central test laboratories to the Councils of National Economy, Ministries, State Committees and other departments for consideration and use in working out measures for a further development and raising the standard of measurement technology and improving the service inspection of measures and measuring instruments under their jurisdiction.

At the same time the Committee explained that in determining the possibility of unifying isolated factory test laboratories into single central test laboratories and establishing the order of their subordination, it is necessary to take into consideration local conditions of operation and the production characteristics of their subordinate organizations.

The Committee instructed its representatives at the Councils of Ministers of the Union Republics, the directors of institutes and heads of state inspection laboratories to assist to the utmost in the reorganization in the work of service inspection agencies of measurement equipment according to the model instruction, and to render the Ministries, Departments, Councils of National Economy, factories and organizations every practical assistance possible in this respect.

The Committee also decided to send the supplement to the model instruction (requirements for the premises and installation of equipment in test laboratories and establishments) to the Committee's representatives at the Councils of Ministers of Union Republics, directors of institutes and heads of state inspection laboratories for use as a guiding document in evaluating the state of premises and the efficiency of installation of the equipment of their measuring-instrument service inspection agencies.

Moreover, the Committee recommended that this document be used as a guide for technical recommendations in designing special buildings or premises for service inspection agencies of factorirs which are under construction, and for re-equipping the premises of existing test laboratories.

SELECTION OF THE NUMBER OF CHECK POINTS ON AN INSTRUMENT SCALE

A. S. Nemirovskii and V. A. Volkonskii

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 5-10,
January, 1961

The development of a theoretical basis for checking instruments has at present acquired considerable importance. Attempts have been made to determine the relation between the grades of accuracy of the measures and measuring instruments. In this article we describe the solution of another such problem, namely, the selection of an optimum number of check points on an instrument scale. This solution could be applied to developing or improving methods of checking a wide range of instruments.

The instruments are normally checked at several points of the scale, and on the basis of these tests it is determined whether the instruments are suitable for measuring values corresponding to the intermediate points of the scale. Obviously, such an estimation cannot be made with complete certainty, but the degree of certainty will be the larger the smaller the difference between the values of two adjacent checking points, i.e., the larger the number of checking points on the scale. On the other hand, in order to raise checking productivity it is desirable to decrease the number of checking points.

In checking instruments errors are discovered which are functions of the instrument scale. As the result of each test an expression for the error is obtained which can be plotted in the form of a curve $x(t)$, whose abscissas t represent the values of the scale and ordinates x represent the errors. The curve errors obtained in a forward calibrating motion do not coincide with those obtained in a reverse motion, owing to backlash and hysteresis irregularities, and the errors of one checking do not coincide with another owing to random errors.

The error curves for a second instrument of the same type will differ from the first owing to the impossibility of manufacturing absolutely identical instruments.

All the possible random expressions for the forward and reverse calibrations of an instrument form an aggregate of expressions of a random function (the instrument errors taken as ordinates, and the nominal values of scale readings as abscissas). Thus, to every set of instruments of a given type there will correspond a set of aggregates of random error expressions which will form an aggregate of random functions, with each random function corresponding to an instrument. The aggregate of random functions is itself a random function.

Hence, the instrument scale error is a random function of a point on the scale and it can be represented by finite-dimensional distribution laws or numerical characteristics consisting of the expectation value, dispersion and correlation function.

The probability characteristics of an error can be established from a sufficient number of expressions for a group of instruments of a given type (for instance, 10-12 models) by taking a large enough number of tests for each instrument (for instance, by measuring 10 times in the forward and 10 times in the reverse direction at 10-20 points). It is difficult to plot multi-dimensional distributions, and in practice it is sufficient to check the nature of a single-dimensional distribution law. It is necessary to compute the dispersion and the correlation function of the error. Methods for computing these values are well known (see, for instance [1]).

Figures 1a and 1b show the computed values of the single-dimensional distribution law and the correlation function for the error of a group of secondary differential manometers.*

* The computation was made by S. M. Kessel'man.

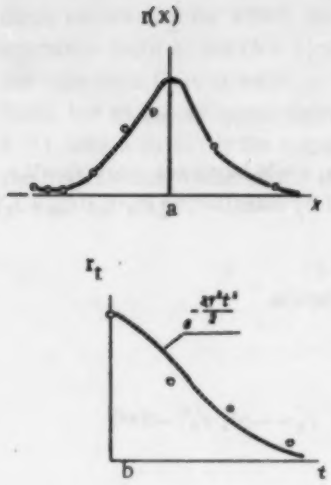

Fig. 1.

Since in calibrating an instrument one strives to reduce the error to zero, it is possible to consider that the expectation value of our random function is equal to zero; moreover, since all the values of the error must lie in the tolerance field (of the grade) and the manufacture and adjustment of instruments is aimed at meeting that requirement in all the points of the scale, we can consider our function to be stationary. Finally, there are more small errors than large ones, and the errors are caused by a large number of small random causes (effective during the manufacture and adjustment of instruments); it is, therefore, possible to consider that the random function is normal (has a Gaussian finite-dimensional distribution).

It will be seen from Fig. 1a that in fact the single-dimensional distribution approaches the normal, and the expectation value approaches zero.

The problem can now be formulated as follows. Considering that the error is a normal stationary random function with a zero expectation value, it is required to find the conditional probability P_c of the error being outside the tolerance field, providing the error of the n checking points remains inside the field, and finding the absolute probability P of the error being outside the tolerance field (without the condition that the errors at the checking points remain inside the field), i.e., finding the probability of the overshoot error after and before checking, and comparing the two values thus obtained.

If probability P_c is substantially smaller than probability P (for instance, by a factor of 100), the checking will provide worth-while results.

Since P_c depends on the correlation coefficient between adjacent checking points, it is possible to chose for a known correlation function the distance between these points so as to make P_c sufficiently small, thus determining by means of this distance the number of checking points on the scale.

In solving this problem we can make use of the following considerations.

1. The probability (absolute even before checking) of the error exceeding the tolerance field (according to the terminology now established in the communication theory and the theory of random functions, we shall call the errors outside the tolerance field overshoots) is small, i.e., the percentage of instruments rejected in checking is small.

2. The error curve as a function of the scale varies, as a rule, very smoothly (over the scale length it has normally not more than one and seldom two oscillations). It is clear, therefore, that more than single overshoot of the tolerance field occurs more seldom than a single overshoot. Therefore, we can assume that the overshoot of the tolerance field (the probability that the instrument is rejected) approaches the expectation value of the number of overshoots (taken in the meaning that their ratio approaches unity).

The admissibility of this assumption can be checked if the correlation function r_t of the error is known.

Let η be the number of overshoots above the level of δ. Then:

$$M\eta - P(\eta=1) = \sum_{k=2}^{\infty} kP(\eta=k) < \sum_{k=2}^{\infty} (k^2-k)P(\eta=k) = M\eta^2 - M\eta.$$

We must prove the smallness of the ratio:

$$\frac{M\eta - P(\eta=1)}{M\eta}.$$

It is possible to prove that:

$$\frac{M\eta^2 - M\eta}{M\eta} = \frac{1}{2}\int_0^T A(t)\exp\left[-\frac{\delta^2}{r_0+r_t}\right]dt \simeq \frac{1}{2}e^{-\frac{\delta^2}{2r_0}}\int_0^{\infty} A(t)\cdot\exp\left[-\frac{\delta^2}{2r_0}\cdot\frac{r_0-r_t}{r_0+r_t}\right]dt$$

where

$$A(f)=\frac{\sqrt{r_0}}{2\pi}\,\frac{-r_0^{\cdot}(r_0^2-r_t^2)^{\cdot}-r_t^{\cdot 3}r_0}{\sqrt{-r_0^{\cdot}}\,(r_0^2-r_t^2)^{5/2}}.$$

Since δ^2/r_0 is usually relatively large, expression $\exp\left[(-\delta^2/2r_0)\cdot(r_0-r_t)/(r_0+r_t)\right]$ becomes very small when r_t is small. It is, therefore, possible to calculate approximately this integral by substituting $(r_0-r_t)/(r_0+r_t)$ under the exponential sign by $-r_0^{\cdot\cdot}t/4r_0$, and substituting expression

$$\frac{\sqrt{r_0}\,[-r_0^{\cdot}(r_0^2-r_t^2)^{\cdot}-r_t^{\cdot 3}r_0]}{\sqrt{-r_0^{\cdot}}\,(r_0^2-r_t^2)^{5/2}} \quad \text{by} \quad \frac{1}{4}\,\frac{r_0r_0^{(4)}-r_0^{\cdot\cdot 2}}{-r_0^{\cdot}r_0}\,t. \quad \text{Whence}$$

$$\frac{M\eta^2-M\eta}{M\eta}<\frac{1}{4\pi}\cdot\frac{r_0r_0^{(4)}-r_0^{\cdot\cdot 2}}{r_0^{\cdot 3}}\,\frac{r_0}{\delta^2}\,e^{-\frac{\delta^2}{2r_0}} \text{ for } r_t=\exp\left(-\frac{\pi^2t^2}{2}\right) \quad (r_0=1;\ r_0^{\cdot}=-\pi^2;\ r_0^{(4)}=3\pi^4)$$

this value is equal to 0,0002 (for $\delta/\sqrt{r_0}=3$) or 0,0053 (for $\delta/\sqrt{r_0}=2$). Thus, the assumption that the probability of overshooting approaches the expectation value of the number of overshoots is confirmed.

3. The probability that the instrument will not be rejected in checking is large. Hence the conditional probability of the existence of an overshoot of the tolerance field, providing this overshoot was not noticed in checking, can be substituted by the probability (absolute) of not noticing the overshoot. The latter probability in turn is very close to the expectation value of the number of unnoticed overshoots. Thus we should compute the expectation value of the total number of overshoots of the tolerance field and the number of overshoots unnoticed during measurements in the discrete aggregate of the checking points.

This mathematical problem has also the following technical application. Let a certain variable in the production process (for instance, the steam pressure in a boiler or the flow of combustible gas supplied to a blast furnace) have random variations which must not exceed a certain fixed value. This variable is measured at equal intervals of time and as soon as an overshoot in the tolerance level occurs a signal is sent indicating the necessity of an adjustment. The problem is, what should be the frequency of measurements in order to make the proportion of unobserved overshoots sufficiently small. For a long observation time the mean proportion of unobserved overshoots is equal to the ratio of the expectation value of the number of unobserved overshoots per unit of time to the expectation value of the number of all the overshoots per unit of time.

Let us return to our problem.

Let the correlation function of the error be r_t (t is the distance between the points on the scale).

The expectation value of the number of intersections in the upward direction on a unit length of a set level δ of a stationary Gaussian process is calculated from the formula

$$\mu=\frac{1}{2\pi}\sqrt{\frac{-r_0^{\cdot}}{r_0}}\,e^{-\frac{\delta^2}{2r_0}} \tag{1}$$

(see, for instance [2] and [3]).

Hence the expectation value of the number of overshoots $\pm\delta$ in the tolerance field (i.e., the number of intersections of level δ and level $-\delta$) is:

$$P_1=\frac{T}{\pi}\sqrt{\frac{-r_0^{\cdot}}{r_0}}\,e^{-\frac{\delta^2}{2r_0}}, \tag{2}$$

where T is the total length of the scale.

On the other hand the number of overshoots in the tolerance field observed during checking is equal to those values of k for which the error is inside the tolerance field at the k-th checking point, and outside the tolerance field at the $(k+1)$-th checking point. The expectation value of the number of noticed overshoots of the tolerance field is equal to the probability that at the given checking point the error lies within the tolerance field, but at the adjacent right-hand side point it lies outside the tolerance field, i.e., that $P(|x_0| < \delta, |x_{T/n}| > \delta)$, where $(n+1)$ is the number of checking points on the scale and x_t is the value of the error at point t. Hence the expectation value of the number of overshoots in all the n intervals is equal to:

$$P_2 = P(|x_0| > \delta) + nP(|x_0| < \delta, \; |x_{\frac{T}{n}}| > \delta) = 2\left[1 - \Phi\left(\frac{\delta}{\sqrt{r_0}}\right)\right] +$$

$$+ \frac{n}{2\pi\sqrt{r_0^2 - r_{\frac{T}{n}}^2}} \times \int_{|x|<\delta} dx \int_{|y|>\delta} \exp\left[\frac{x^2 - 2r_{\frac{T}{n}}\, xy + y^2}{r_0 \; 2(r_0^2 - r_{\frac{T}{n}}^2)}\right] dy, \qquad (2)$$

and the expectation value P_3 of the number of unnoticed overshoots is equal to the difference of expressions (2) and (1):

$$P_3 = \frac{T}{\pi}\sqrt{\frac{-\dot{r}_0}{r_0}}\, e^{-\frac{\delta^2}{2r_0}} - \frac{n}{2\pi\sqrt{r_0^2 - r_{\frac{T}{n}}^2}} \int_{|x|<\delta} dx \int_{|y|>\delta} \exp\left[-\frac{x^2 - 2r_{\frac{T}{n}}\, xy + y^2}{r_0 \; 2(r_0^2 - r_{\frac{T}{n}}^2)}\right] dy \; 2\left[1 - \Phi\left(\frac{\delta}{\sqrt{r_0}}\right)\right]. \qquad (3)$$

This value is somewhat larger than the one in which we are interested, since the expression with the noticed overshoots may contain other overshoots in the intervals between the adjacent checking points. They are taken into consideration only in expression (1) but not in formula (2); thus in computing P_3 the "unobserved" overshoots which are indirectly determined by the presence in the same expression of observed overshoots are also taken into consideration.

The formula obtained for P_3 is inconvenient, since the integral included in it is difficult to calculate or investigate. Therefore the expression for P_3 should be computed in a different manner.

The probability f that segment $[t, t+dt]$ will have an overshoot which will not be observed in checking is equal to the product of the probability that this segment will have an overshoot by the probability (conditional) that the overshoot which started at point t will be completed to the left of the subsequent checking point $\tilde{t}$.

The probability that an overshoot will start in segment $[t, t+dt]$ is equal to $\mu\, dt$, where μ is the expectation value of the number of overshoots per unit time – see [1]. Hence:

$$f = \mu F(\tilde{t} - t)\, dt,$$

where $F(x)$ is the conditional probability of an overshoot which started at point 0, being completed to the left of point x.

The expectation value of the number of unobserved overshoots in the tolerance field $(-\delta, \delta)$ over the whole scale is:

$$P_4 = 2n\int_0^{\frac{T}{n}} F\left(\frac{T}{n} - t\right) \mu\, dt = 2n\int_0^{\frac{T}{n}} \mu F(t)\, dt. \qquad (4)$$

Since we only calculated the number of overshoots of a small length (smaller than T/n), it is possible to consider in the first approximation that the second derivative $x_t^{\cdot\cdot}$ of the error process remains constant during the overshoot (and the overshoot has the shape of a parabola). Moreover, with a rising level δ the conditional expectation value of the second derivative $x_t^{\cdot\cdot}$ is $(r_0^{\cdot\cdot}/r_0)\,\delta$, providing the value of the process itself is $x_t = \delta$, i.e., the above expectation value is proportional to δ. At the same time the conditional standard deviation of $x_t^{\cdot\cdot}$ will not be altered. It is equal to:

$$\sqrt{r_0^{(4)} - \frac{r_0^{\cdot\cdot 2}}{r_0}}.$$

It is therefore possible to assume in the first approximation, when computing the length of the overshoot, that:

$$x_t^{\cdot} = \frac{r_0^{\cdot}}{r^0}\,\delta.$$

For these assumptions

$$F(t) = 1 - e^{-\frac{\delta^2 r_0^{\cdot} t^2}{8 r_0^2}} \tag{5}$$

see Rice [3], formula (65).

From the above and (4) we have:

$$P_3 = 2\mu T\left\{1 - 2\frac{n}{T}\sqrt{\frac{r_0}{-r_0^{\cdot}}}\,\frac{\sqrt{r_0}}{\delta}\sqrt{2\pi}\times\left[\Phi\left(\frac{T\delta\sqrt{-r_0^{\cdot}}}{2nr_0}\right) - \frac{1}{2}\right]\right\}. \tag{6}$$

Example 1. Let us assume that T = 1 and examine the correlation function of the form: a) $r_t = e^{-\frac{3,7^2 t^2}{2}}$ (this correlation function was derived by processing experimentally obtained errors of a group of instruments. The function is shown in Fig. 1b); b) $r_t = e^{-\frac{1}{2}\pi^2 t^2}$ (see Fig. 2a); c) $r_t = (1/2\pi t)\sin 2\pi t$ (see Fig. 2b).

The last two correlation functions decay at half the scale length.

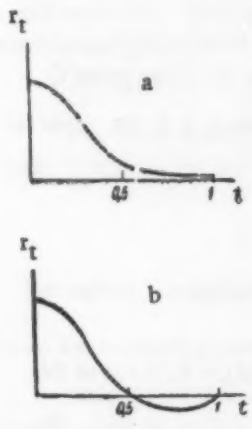

Fig. 2.

As the result of computations we have: for the case "a", $r_0^{\cdot\cdot}/r_0 = 3,7^2 = 13,6$; for the case "b," $r_0^{\cdot\cdot}/r_0 = \pi^2 = 9,85$; for case "c," $r_0^{\cdot\cdot}/r_0 = (2\pi)^2/3 = 13,1$.

From these data the values of P_1, P_3 and P_3/P_1 have been calculated for various values of $\delta/\sqrt{r_0}$ and n (see table).

From the solution of this example it follows that if the correlation of the error decays in the middle of the scale length, five points are insufficient for calibration, since the percentage of rejects unobserved during checking owing to the overshoot occurring between the checking points is only decreased by a factor of 10-20 (of P_1/P_3) as compared with rejects before checking. For a somewhat lower tolerance level (larger $\delta/\sqrt{r_0}$) calibration at the same checking points gives better results (P_1/P_3 will be somewhat higher), since with a lower tolerance level the expectation value of the overshoot length is larger and easier to detect in checking.

It was assumed in the second paragraph that the existence of any overshoot of the tolerance field leads to the rejection of the instruments. It is only natural, however, to pass the instrument if the amount by which the tolerance field is exceeded is very small (for instance, smaller than $\Delta = 0,05\,\delta$). We shall show that under conditions of our example only an insignificant number of overshoots exceeds the level of $\pm 1,05\,\delta$.

Values of quant.	P_1		P_3		P_3/P_1		
n	5		5		5		30
Cases	a, c	b	a, c	b	a, c	b	a, b, c
$\frac{\delta}{\sqrt{r_0}}=2$	0,155	0,135	0,0065	0,0044	0,042	0,032	0,01
$\frac{\delta}{\sqrt{r_0}}=3$	0,013	0,011	0,0013	0,0007	0,102	0,065	0,01

Assuming that $x_t^* = r_0^* \delta / r_0$ and that the shape of the overshoot x_t^* does not change (the justification of this assumption was given before), we can consider, as we did before, that the length of the overshoot has the distribution given in (5). Thus, the overshoot is a parabola and its height and length are related by the expression:

$$h = -\frac{\dot{x}_0}{2}\frac{l^2}{4}.$$

Let us now compute the probability of an overshoot which exceeds the level of $\Delta + \delta$ (i.e., $h > \Delta$) being undetected providing this overshoot started at the point $\underline{t}$ of level δ. Since the overshoot has not been detected its length must be less than $[(T/n)-t]$, where T/n is the interval between adjacent points on the scale, and $\underline{t}$ is the distance from the beginning of the interval to the beginning of the overshoot. Since the overshoot is higher than Δ, its length must be larger than

$$l_\Delta = \sqrt{\frac{8\delta}{-\dot{x}_0}} = \sqrt{\frac{8r_0\Delta}{-\dot{r}_0\delta}}. \tag{7}$$

Thus, the probability of the overshoot at point $\underline{t}$ on level δ being undetected and at the same time being higher than level $(\delta + \Delta)$ is equal to:

$$P_4 = F\left(\frac{T}{n} - t\right) - F\left(\sqrt{\frac{8r_0\Delta}{-\dot{r}_0^*\delta}}\right). \tag{8}$$

By operations similar to those for deriving formula (4) it is possible to find that the probability of an undetected overshoot having a height $h > \Delta$ is:

$$P_5 = 2n\mu \int_0^{\frac{T}{n}-l_\Delta} \left[F\left(\frac{T}{n} - t\right) - F\left(\sqrt{\frac{8r_0\Delta}{-\dot{r}_0^*\delta}}\right)\right] dt. \tag{9}$$

(the top limit is $[(T/n) - l_\Delta]$ since the overshoots have a length larger than l_Δ).

By using formula (5) we obtain for $l_\Delta < T/n$:

$$P_5 = P_1 \frac{n}{T}\left\{\left(\frac{T}{n} - l_\Delta\right)e^{-\frac{\Delta\delta}{r_0}} - 2\sqrt{2\pi}\sqrt{\frac{r_0}{-\dot{r}_0^*}}\cdot\frac{\sqrt{r_0}}{\delta}\times\left[\Phi\left(\frac{T}{n}\cdot\frac{\delta\sqrt{-\dot{r}_0^*}}{2r_0}\right) - \Phi\left(l_\Delta\frac{\delta\sqrt{-\dot{r}_0^*}}{2r_0}\right)\right]\right\}. \tag{10}$$

If, however, $l_\Delta \geq T/n$, then all the unobserved overshoots above level δ have a height smaller than Δ, and there are no independent overshoots which do not come within the field of $\pm(\delta + \Delta)$.

It can be easily checked that under the conditions of the previously examined example in case "a" ($-r_0''/r_0 = 13{,}6$) for $\Delta = 0{,}05\,\delta$, $n = 5$ and $\delta/\sqrt{r_0} = 3 l_\Delta > T/n$, i.e., $P_5 = 0$.

Since P_5 was calculated approximately (in the assumption that $x_t'' = Mx_0''$), in fact $P_5 \neq 0$, but the probability of an overshoot of the tolerance field of $\pm 1{,}05\,\delta$ is negligible.

For $\delta/\sqrt{r_0} = 2$ the conditional expectation value for the second derivative x_t'' is only 2/3 (in absolute value) of that for $\delta/\sqrt{r_0} = 3$, providing $x_0 = \delta$. Therefore the unobserved overshoots in the case of $\delta/\sqrt{r_0} = 2$ will be of a smaller height than for $\delta/\sqrt{r_0} = 3$.

The accuracy of formula (10) increases with a rising level of x_t''. For low tolerance level standard deviation x_t'' becomes comparable to Mx_t'' and the tangible part of the overshoots has a derivative at the point of overshooting larger than Mx_t'', and these overshoots have a height larger than the height of the corresponding Mx_t''. Under these conditions formula (10) becomes inaccurate and it is then better to calculate with a margin by replacing x_t'' by

$$a_t = -\left(|M_y x_t'| + k\sqrt{D_y x_t'}\right), \tag{11}$$

where M_y and D_y are the conditional expectation value and the dispersion of the second derivative at point t, providing $x_0 = \delta$ at point 0. They are equal to:

$$M_y x_t' = \frac{r_t'}{r_0}\,\delta;\quad D_y x_t' = r_0^{(4)} - \frac{r_t''^2}{r_0}. \tag{12}$$

In order to calculate with a margin it is necessary to take max a_t for $0 < t < T/n$. Normally a_t attains a maximum for $t = 0$.

Coefficient k should be made equal to 1,5 – 2; its value should rise as that of $\sqrt{D_y x_t''}$ with respect to $M_y x_t''$.

In this computation there is no overshoot when:

$$\Delta > \frac{1}{8}\,a_{\max}\left(\frac{T}{n}\right)^2. \tag{13}$$

Example 2. For $\delta = 3\,r_t = e^{-\frac{\pi^2 t^2}{2}}$; $r_0^{(4)} = 3\pi^4$; $r_0'' = \pi^2$; $r_0 = 1$, we obtain from formulas (12) that $Mx_0'' = -3\pi^2$; $Dx_0'' = 2\pi^4$. When $a_{\max} = 3\pi^2 + 2\sqrt{2\pi^4} = 6\pi^2$. For $n = 5$

$$\Delta > \frac{1}{8}\,a_{\max}\left(\frac{1}{n}\right)^2 = 0{,}3 = 0{,}1\delta.$$

It will be seen from the solution of this example that in this case it is possible to eliminate rejects providing the tolerance at the checking points is reduced by a factor of 1,1 as compared with the grade of the instrument.

SUMMARY

The solution described in the article is applicable when the grade of the instrument is determined by the maximum permissible limiting error for maximum permissible relative error, if the notations for errors adopted in the article apply in the first case to the limiting error, and in the second to the relative error.

In solving the questions certain obvious assumptions were made which consist of the following.

There is an error at each point of the scale. Thus it becomes a function of the position on the scale of the instrument and the aggregate of all such functions, obtained for a group of instruments of a given type by means of repeated tests in the forward and reversed direction, may be considered as a stationary random function which has a normal distribution and an expectation value equal to zero.

Such an idealized representation is close to the actual one (and this is demonstrated by the example given in the article); the degree to which the deviation of this representation from the actual one affects the results can be evaluated when experience is gained in applying the above method.

From the data of checking a group of instruments it is easy to calculate the error correlation function (such calculation methods are well known, see for instance [1]), which is required for computing the number of checking points.

With the above assumptions it is easy to calculate the probability of the tolerance field being intersected by the curve which represents the error before checking, corresponding to formula (2), and the probability of overshoot of the tolerance field and a return to the field inside the interval between adjacent checking points, which corresponds to formula (6), i.e., to calculated probability P_1 of rejects before testing and the probability P_C of rejects unnoticed during testing.

The above method consists in the computation and comparison of these two values. The smaller the ratio of P_C/P_1 the more effective is the checking. Having determined the required effectiveness of checking, it is possible to calculate $\underline{n}$, the number of checking points, since $\underline{n}$ is included in the expression for P_C – see formula (6).

In this article a case is examined in which the permissible error at the checking points is reduced with respect to the maximum permissible error. A very small decrease in this error gives striking results in raising the effectiveness of checking.

The above method makes it possible to select a reasonable number of checking points, i.e., to eliminate unobserved rejects if their number is insufficient, or to reduce the checking time if their number exceeds the minimum required.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

LINEAR MEASUREMENTS

EXPERIENCE OF THE 1st GPZ (STATE BEARING PLANT) IN THE USE OF SPRING MEASURING HEADS

N. V. Smelovskii and M. E. Galkin

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The workers of the 1st GPZ are busily engaged in automation and mechanization of production and control, in improving the technology of production and the quality of the products.

In the competition to fulfill the Seven-Year Plan ahead of time the workers of the plant contracted to several enlarged socialist pledges. Owing to the improvement in the quality and increased life of the bearings produced by the plant, it is planned to save at least 50 million rubles during the seven-year period.

In order to be able to fulfill this pledge together with other measures, it was decided to use improved measuring heads. The Leningrad tool-making plant produces such improved measuring heads of the IGP type, which are also known under the name "mikrokators." As compared with the previously made measuring heads of the minimeter type, these new heads are more compact, simpler in construction, more sensitive and accurate and have no error due to backlash, which is especially important in precision measurements.

Owing to the above advantages of the spring-type heads they are now being widely used in the 1st GPZ plant for checking and sorting details and complete bearings. At present we are using these heads with calibrations of 2, 1, 0.5 and 0.2 μ. Heads with calibrations of 5 μ are also being introduced. These heads are widely used both in checking and production processes. Workshops which previously used minimeter-type heads with calibrations of 2 and 1 μ are now using exclusively spring-type measuring heads.

Mass assimilation of these heads required considerable preparatory work by the heads of the OTK (Technical Control Division) and production departments. An instruction on the use of these heads has been issued, seminars and courses for foremen, inspectors, storekeepers and bench-hands were held on the methods of using and storing spring-type measuring heads.

For repairing and adjusting these heads a special department was set up in the factory toolroom which fully met the plant requirements in the repair of these instruments. An analysis of the current use of mikrokators has established that they are more reliable than minimeters; there were only a few cases when mikrokators were rejected owing to loss of accuracy. This has made it possible to extend the periods of routine checking of mikrokators as compared with minimeters by a factor of 2-2½.

The repair-free period of mikrokators is 5-6 times longer than that of minimeters. This alone shows how great is the saving due to the introduction of these instruments. If at the same time it is taken into consideration that their accuracy is higher than that of minimeters, the expediency of introducing mikrokators becomes obvious.

The experience in using spring-type measuring heads has also revealed some of their defects. The manufacturing plant eliminated these defects as they were being indicated by us.

However, the manufacturing plant still has, in our opinion, a few defects to deal with. These deficiencies include the following.

1. Loss of its elasticity by the helical spring during operation, which prevents the pointer from attaining its extreme right-hand side position.

2. An excessive projection of the front angle-piece holding plate which serves to tighten the helix. This large projection bends the plate, which is another cause preventing the pointer from reaching its extreme right-hand side position.

3. Sticking of the pointer against its stop during measurements.

4. Insecure fixing of the glass, which makes it sometimes drop out when cleaned during current use. It is recommended that a fixing be added at the bottom end of the glass.

5. The penetration in some cases of emulsions and moisture into the instrument when used on machines. This is caused by an insufficiently tight fixing of the lid to the body of the instrument, and often leads to its failure. In order to prevent this a hermetically tight fixing should be provided.

6. Stripping of threads in the lid by fixing screws. It is advisable to mount metal bushes for fixing screws in the lids.

7. It should also be remembered that the heads have to be checked for accuracy at certain intervals during operation. When this is done their serial number has to be checked against their testing certificates. This leads to difficulties, since the heads are usually permanently fixed to instruments, and in order to be able to read the number they have to be dismounted. This produces a loss in the adjustment of the instrument and the need for subsequent readjustment, thus leading to a considerable waste of time. It is recommended that the serial number be printed on the face of the head.

At the same time the size of the type on the stamp should be increased from 2 mm to $3\frac{1}{2}$-4 mm; this will simplify the method of checking heads in periodic inspections.

The rectification of the above defects will raise the quality of the spring-type heads and lead to their adoption in place of minimeters in all the bearing plants.

Editorial Note: According to a report from LIZ (Leningrad Instrument-Making Plant) some of these defects are already being dealt with, and the remainder will be taken into account in the next improvement of the design; the durability of mikrokators is 8-10 times greater than that of minimeters. An increase in the size of the serial number is, in the opinion of the manufacturing plant, not advisable.

INSTRUMENT FOR CHECKING SLIDE GAUGES

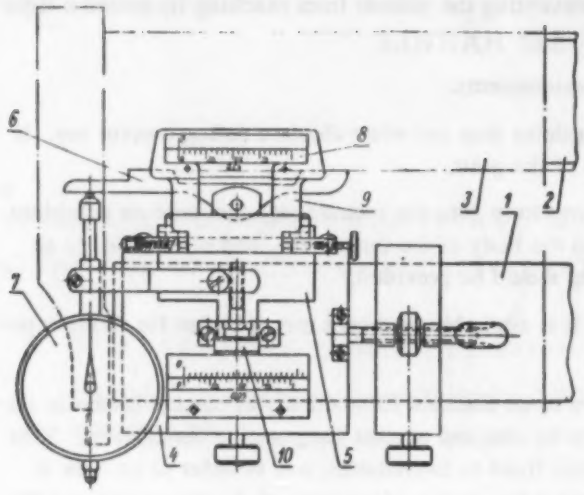
A. S. Kapsevich and V. K. Myshakin

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 11-12,
January, 1961

In the "15th Anniversary of the LKSMUk" (Leninist Young Communist League of the Ukraine) Engineering Plant V. K. Myshakin developed an instrument for highly productive checking of slide gauges of large sizes from 300 to 2000 mm without the use of end gauges. The method is based on comparing slide gauges with a reference slide gauge.

Reference beam 1 is fixed to the front of a rigid base (see figure), and its back carries rest bar 2, on which the tested slide gauge 3 is placed.

Beam 1 carries frame 4 with a vernier scale, a spring and a stop screw, made in the manner of normal slide-gauge frames. The frame carries a measuring device consisting of a carriage 5 which under spring action is displaced on guide rails in a direction perpendicular to beam 1. To the back of the carriage, lever 6 is fixed on an axle, with one end of the lever resting against the measuring stem of indicator 7 placed on the carriage.



For comparing readings of the reference beam with the slide gauge, frame 4 carries a second vernier scale 8 fixed to a separate frame 9, which is mounted on the axle. Both vernier scales are calibrated in 0.05 mm.

Frame 9 together with its vernier can be displaced along the beam by 4 mm and withdrawn from the beam in a vertical direction.

A precise adjustment of the measuring device is carried out by means of the frame microdrive, in a manner similar to normal slide gauges.

The tested slide gauges are fixed to the instrument by means of two stops and three stop screws (clamps).

In checking slide gauges the measuring device of the instrument is adjusted to its zero position and the stops to each side of the gauge. The tested slide gauge is placed on the instrument in such a manner that it rests on the stops and its zero mark coincides with that of the vernier scale, the gauge is then secured by the clamp screws and the stops withdrawn. The lever together with its carriage is then approached by means of screw 10 to the lower guide rail of the beam, so that the indicator has a negative allowance of about 1 mm. When the measuring device is displaced from left to right along the beam, the indicator will measure deviations.

When repeated tests of slide gauges carried out by means of this instrument were compared with those obtained by means of end gauges according to specification No. 136 of the Committee of Standards, Measures and Measuring Instruments, it was found that the results obtained by means of these two methods coincided.

The instrument is easy to use, it is sufficiently accurate and is highly productive. The time spent on checking is reduced to 1/3 or 1/4.

MODERNIZED HORIZONTAL COMPARATOR

E. I. Finkel'shtein

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January, 1961

The factory test laboratories are now supplied with reference linear scales for calibrating measuring and universal microscopes, and it is therefore necessary to have instruments for calibrating these scales. The only available horizontal comparator IZA-2 for testing such scales is not satisfactory, mainly owing to its errors.

On the basis of this comparator we have developed and constructed an instrument free from the above and other drawbacks.

The main differences between the new instrument (Figs. 1 and 2) and comparator IZA-2 are the following.

The two separate microscopes have been combined into one fixed microscope with a magnification of 72 diameters and a common field of vision, but with two different inputs placed respectively against the two compared scales.

The left branch of the microscope includes an optical micrometer with calibrations of 0.2 μ.

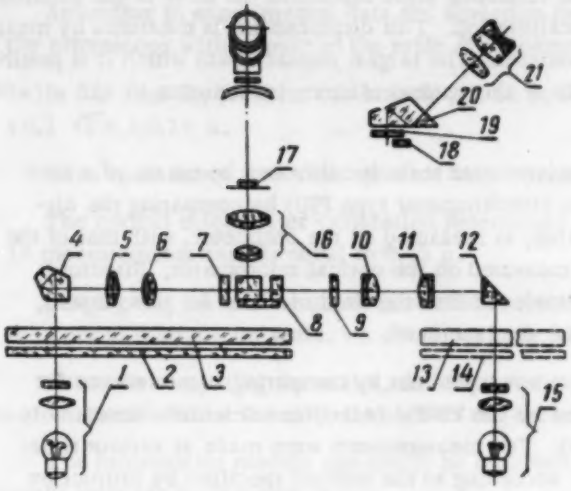

Fig. 1. Optical layout of a modernized horizontal comparator. 1 and 15) illuminator with condenser and protective opal glass; 2, 3, 13 and 14)the reference and tested scales with glass covers; 4 and 12) prisms for changing the direction of rays; 5, 6, 10 and 11) lenses for projecting the image of the graduations on to block 8; 7) plane-parallel plate of the optical micrometer; 8) dividing prismatic block; 9) adjusting plane-parallel plate for making the zero calibrations coincide at the beginning of testing; 16) microscope objective; 17) light filter; 18) optical micrometer scale which is rigidly connected to plate 7; 19) fixed grating; 20 and 21) inclined eyepiece.

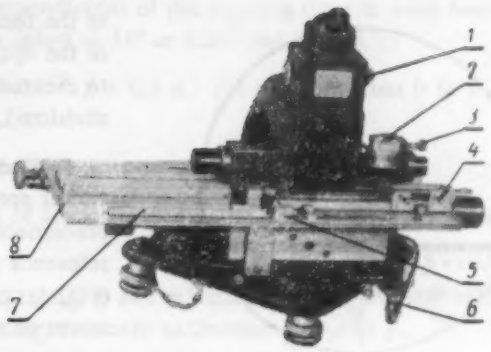

Fig. 2. Modernized horizontal comparator. 1) Fly-wheel knob for the optical micrometer; 2) measuring head for making the two zero calibrations coincide before starting measurements; 3) fly-wheel knob for focusing; 4) screws for transverse displacement of the measured scale and its tilting in the horizontal plane; 5) fly-wheel knob for tilting the scale in the vertical plane; 6) illuminator with diaphragms for equalizing illuminator of the left and right-hand sides of the field of vision; 7) external (approximate) scale; 8) ground plate on which the instrument rests when determining the value of the optical micrometer calibrations.

The deviations of the table from a rectilinear movement have been reduced to 10".

Similar to a normal-type IZA-2 comparator, the measurement of the deviations in the actual intervals of the tested scale as compared with their nominal values is attained by comparing it with a basic reference scale by means of the longitudinal comparison method.

Both the reference and tested scales are placed on a movable table, respectively under the left and right-hand branches of the microscope, and the graduations of both scales are simultaneously viewed by means of one eye in a common field of vision. The left branch is focused onto the plane of the reference scale; the right branch is focused onto the tested scale by displacing lens 11 (Fig. 1) along its axis.

The distance between the microscope inputs amounts to 280 mm, thus making it possible to measure scales 200 mm long.

Through the field of vision of the instrument (Figs. 3, 4) there runs a thin line which divides the field of vision into two equal parts, each of which corresponds to one of the branches of the microscope; in this field one can see simultaneously the upper part of the left-hand branch field and the lower part of the right-hand branch field, both rotated through 90°. Thus, during measurements one will see the top half of the reference scale calibrations and the lower half of the tested scale calibrations.

The images of the zero graduations of the reference and tested scales are approached to the middle of the dividing line by rotating plate 9 (Fig. 1) and are made to coincide in a similar way to the graduations of an optical theodolite angle-measuring scale.

By displacing the table, which carries both scales, the remaining calibrations of both scales are approached to the dividing line in the required intervals. If there is an error in any given interval the calibrations will appear displaced with respect to each other along the dividing line. The value of the displacement multiplied by

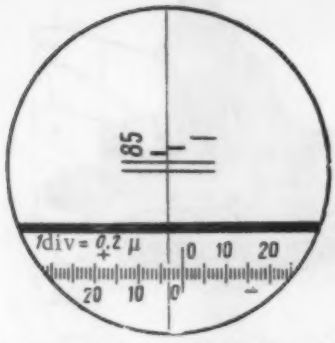

Fig. 3. Field of vision before the graduations are made to coincide.

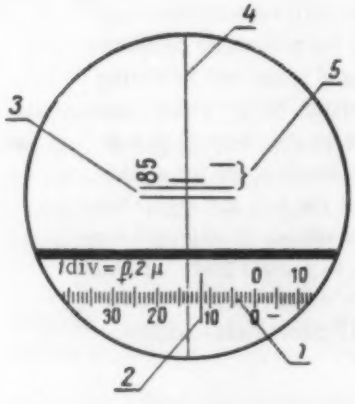

Fig. 4. Field of vision after the graduations of the reference and tested scales were made to coincide by means of an optical micrometer. 1) Micron scale; 2) index of the micron scale; 3) bisector for determining the value of the micron scale calibration; 4) dividing line; 5) zone of graduation coincidence. The reading (12 divisions) corresponds to an error of the tested scale at that point equal to 2.4 μ.

the correction of the reference scale represents the error in the position of the tested scale calibration. This displacement is measured by means of the optical micrometer. The largest displacement which it is possible to measure by means of this optical micrometer amounts to ±10 μ (±50 divisions).

The optical micrometer scale is calibrated by means of a horizontal optimeter (or interferometer type PIU) by comparing the displacement of the table, as measured on the optimeter, with that of the reference scale, as measured on the optical micrometer. Bisector 3 (Fig. 4) specially introduced into the field of vision for this purpose, serves to measure this displacement.

The instrument was tested out by comparing two reference 1st grade scales certified by the VNIIM (All-Union Scientific Research Institute of Metrology). Ten measurements were made at various times during two months, according to the method specified by instruction 82-56.

The mean difference in the reading of the two scales with appropriate correction was found to be equal to 0.32 μ with a maximum difference of 0.55 μ.

Let us now analyze the maximum deviation thus obtained.

The main measurement error was due to the error in the calibration of the basic reference scale. In this instance we took as the basic scale a 1st grade scale certified by the VNIIM for a maximum error of $\Delta_1 = \pm 0.3$ μ.

The second source of errors is due to temperature phenomena. If we assume that the difference in the linear temperature coefficient of the reference and tested scales amounts to $1 \cdot 10^{-6}$ and that the measurements could be made at a temperature differing from 20° by 1°C, then for a scale length of 200 mm the resulting error will amount to $\Delta_2 \pm 0.2$ μ.

The third element which affects the accuracy of measurements consists of the perpendicularity of the sighting axes of the left and right-hand side branches of the instrument to the direction of the table displacement in the presence of a vertical slope of the scales.

The slope of the scale is due to the fact that it is adjusted in the vertical plane by the sharpness of the graduations' focusing at the ends of the scale and, hence, the error in the setting may occur within the range of the depth of focusing. The full depth of focusing is equal to $T = T_g + T_w$, where T_g is the geometrical depth and T_w is the wave depth caused by diffraction phenomena. We neglect the physiological depth due to the width of accommodation, since the grating placed in the field of vision provides the required accommodation for the eyes.

Assuming that the limiting angular value of a dispersion circle observable by the eye is equal to 2', we obtain [1]:

$$T = T_g + T_w = \frac{1}{7A\Gamma} + \frac{\lambda}{2A^2}.$$

In our case the aperture A = 0.1; the magnification Γ = 72 diameters and the wavelength λ = 0.56 μ. Hence T = 50 μ or, reckoning from the middle position, T = ± 25 μ. The maximum value by which one end of the scale can be higher than the other is $h = 25\sqrt{2} = 35$ μ and the angle of slope $\alpha_1 = 0.000175$ rad.

According to experimental data the deviation from the perpendicular of the sighting lines in each branch of the microscope with respect to the table displacement can be taken as 10' or 0.003 rad.

In this case the error for one branch will be equal to $35 \cdot 3 \cdot 10^{-3}$ $\mu = 0.1$ μ. For both branches it is $\Delta_3 = \pm 0.1 \sqrt{2} = \pm 0.14$ μ.

Tests have shown that each operator has a personal error in the limits of $\Delta_4 = \pm 0.15$ μ.

The optical micrometer calibration determined by means of an optimeter in three series of measurements of 10 measurements each is equal to 0.22 μ.

Considering the measurement error of the optimeter equal to 0.3 μ and referring it to the 100 divisions of the optical micrometer scale, we obtain an error for determining the scale calibration of 0.003 μ.

Since, in comparing the scales, the displacement of the calibrations does not exceed 7 μ, or 35 divisions, the error introduced by the micrometer will not exceed $\Delta_5 = 0.003 \times 35 = 0.1$ μ.

The micrometer reading can easily be obtained with an error of 0.2 divisions, which corresponds to a measurement error of $\Delta_6 = \pm 0.04$ μ.

The slope of the scale in the vertical plane is the same as in the horizontal plane, as has already been pointed out, and is equal to 0.000175 rad. Hence, for a scale length of 200 mm the corresponding measurement error is equal to $\Delta_7 = 100 \cdot 0.000175^2$ mm $= \pm 0.003$ μ.

The axes of the scales do not lie strictly in the same vertical plane owing to the corresponding displacement in the branches of the microscope. Assuming this displacement equal to $s_1 = 0.5$ mm we shall obtain the value of $\Delta_8 = \pm s_1\alpha_3 = \pm 0.08$ μ for a deviation from a rectilinear movement of the table in the horizontal plane of $\alpha_3 = 30''$.

The axes of the scales do not lie in strictly the same horizontal plane either, owing to the possible difference in the thickness of the scales. Assuming this difference to be $s_2 = 1$ mm and the deviation from a rectilinear movement of the table in the vertical direction to be $\alpha_4 = 10''$, we obtain for $\Delta_9 = \pm s_1\alpha_4 = \pm 0.05$ μ.

Measurements of the error of calibration coincidence in the field of vision have shown that the quadratic mean error is $\sigma = \pm 0.13$ μ; hence, the limiting error of adjustment is equal to $3\sigma = \pm 0.39$ μ. Since, according to instruction 82-56 on checking reference scales, the measurement is made in four series of 6 measurements each, the error of coincidence is reduced by a factor of 5.

Hence, the limiting error due to the imperfect coincidence of the calibrations is:

$$\Delta_{10} = \pm \frac{0.39\sqrt{2}}{5} = \pm 0.11 \ \mu.$$

The two branches of the microscope have a certain difference in magnification, which does not exceed 0.1%, which amounts to 1 μ for 1 mm of the field of vision. Since the measuring zone is limited by field of vision graduations placed at a distance of 0.03 mm, the maximum error due to the difference in magnification will be equal to $\Delta_{11} = \pm 0.03$ μ.

The error due to illumination and focusing has been assumed by us, on the basis of experiments, to be equal to $\Delta_{12} = \pm 0.1$ μ.

Assuming that the above errors are approximately random and adding them up according to the law of accumulated errors, we can find the approximate value of the limiting total measurement error which is equal to

$$\Delta = \pm \sqrt{\Sigma \Delta_i^2} = \pm 0.45 \ \mu,$$

which is in good agreement with experimental data. It can be assumed, therefore, that the above instrument may be used for checking 2nd grade reference scales.

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2. A. N. Koroleva and A. D. Zagatina, Methods of Measuring Small Dimensions Scales, Trudy VNIIM, 37/97, 1959.

DEVICE FOR CHECKING OPTICAL QUADRANTS

F. P. Volosevich

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, p. 15, January, 1961

Below we describe a device which we developed and used for measuring optical quadrants, and which consists of an autocollimator, a case and a prism (Fig. 1).

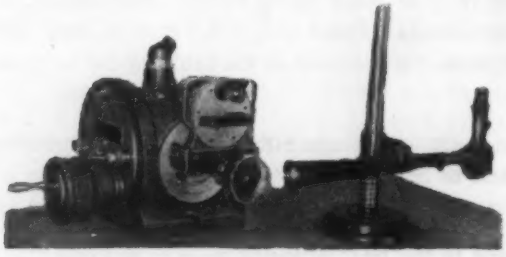

Fig. 1.

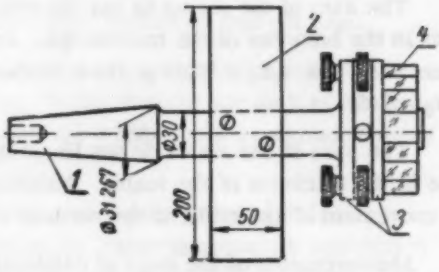

Fig. 2.

The autocollimator consists of a modified optimeter head whose vibrating mirror and objective have been removed, and whose tube has been extended by an appropriately designed conical extension piece with an objective of a focal length of 500 mm, which provides a measurement error not exceeding 10". The autocollimator is mounted on a support in such a manner that its position can be adjusted.

Casing 1 (Fig. 2) ends in a Morse cone No. 4, used for coupling it to the hollow spindle of an optical dividing head (ODG), which serves as a measuring and rotating mechanism for checking quadrants. The casing has a shelf 2 on which the checked instruments are placed and an adjustable table 3, similar to a table of a vertical optimeter. The table carries a 12-sided silvered glass prism 4, certified for an error not exceeding ± 3".

The optical quadrant under test is placed on the shelf of the casing which is coupled to a dividing head and is tested at the check points according to instruction 112-56.

The above device can also be used successfully for checking optical dividing heads according to instruction 113-56 and commercial levels according to instruction 131-57, and provides a higher productivity in checking, with the required degree of accuracy, as compared with the methods described in instruction 112-56.

DEVICE FOR ADJUSTING UNIVERSAL AND MEASURING MICROSCOPES

N. K. Krasnoperov

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January, 1961

At the Noginsk plant of fuel equipment a device was made for eliminating the displacement of the optical axis of a type UIM-21 and BMI microscope tube with respect to the axis of rotation of the supporting column.

The device (Fig. 1) consists of a collar which is placed on the bracket and the tube, and is made up of two sections 1 and 2 (Fig. 1), which are clamped together by bolts 9.

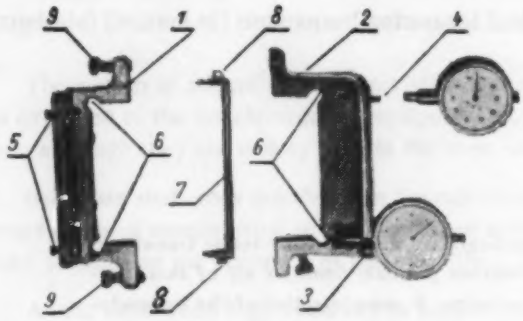

Fig. 1.

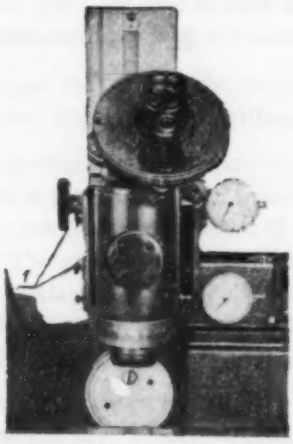

Fig. 2.

The right-hand side wall of the collar carries on fixing screws 3 miniature indicating heads calibrated in 0.01 mm, and in addition is supplied with two adjusting screws 4.

The other half of the collar also has two adjusting screws 5 and two bolts 1 (Fig. 2), which provide a more rigid fixing of the device to the bracket of the microscope tubes. The four holes 6 (Fig. 1) provide access, after the collar has been fixed to the bracket, to the heads of the screws which fix the microscope tube to the bracket.

Plate 7, which is fixed to the microscope tube by means of two screws 8, serves as a resting plate for the tips of the indicating heads.

The operating position of the device is shown in Fig. 1.

The position of the optical axis of the microscope tube is checked by means of a cylinder with an indicating blade placed between the bearing centers and designed to be in the plane of the centers (in the absence of an indicating cylinder it is possible to use the tip of one of the centers). In the zero position of the supporting pillar the indicating blade of the cylinder is brought sharply into focus, and then the point of intersection of the eyepiece hairlines is made to coincide with the sharp edge of the indicating blade.

The microscope pillar is then deflected to the left and the right from its zero position through 12.5°, and the variation in the focusing and position of the sharp edge of the blade with respect to the center of the crosshairs is observed through the eyepiece.

If the rotation of the pillar does not change the sharpness of the image, but the intersection of the hairlines is displaced from the blade image by a distance greater than the tolerance, it means that the axis of the centers does not coincide with the axis of rotation of the pillar. This defect should be eliminated by the method described in [1].

If the displacement of the blade image is accompanied by a blurring of the image, it means that the optical axis of the microscope tube is displaced with respect to the axis of rotation of the pillar. This defect can be eliminated by means of the device here described in the following manner.

1. The device is fixed to the microscope tube (see Fig. 1).

2. The tips of the indicator heads are made to rest against plate 7, the required negative allowance is established and the indicators are set to zero.

3. The fixing screws of the microscope tube to the bracket are loosened by means of a screw-driver through holes 6.

4. The microscope tube is displaced to one side by means of the adjusting screws 4 and 5 in such a way that both indicator pointers are deflected by the same amount. This will displace the optical axis to one side in a plane parallel to itself.

5. The microscope pillar is then rotated to the right and left from its zero position through 12.5° and the variation in focusing is observed through the eyepiece. The tube is readjusted until the focusing does not change with the rotation of the tube.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

MECHANICAL MEASUREMENTS

UNIFORMITY OF MEASUREMENTS IN THE SPHERE OF ACCELEROMETRY*

P. N. Agaletskii and V. I. Kiparenko

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January, 1961

The system of metrological supervision over measures and measuring instruments has up to the present not been extended to the accelerometric equipment and certain other instruments intended for dynamic measurements, although they are widely used in the most varied spheres of science, industry and transport.

Below we shall only use the term "accelerometer" with respect to instruments which are designed for direct measurements of acceleration in the prescribed units with the required accuracy, and we shall examine questions related to ensuring the accuracy of their readings.

At the time when high accuracy in accelerometer readings was not required, and differences in readings of these instruments exceeding 15-20% did not cause any anxiety, there was no practical necessity in organizing a centralized metrological control in order to ensure uniformity of readings in the sphere of accelerometry.

Now it is often required to have an error in accelerometer readings not exceeding ±3%, i.e., to have differences in instrument readings not exceeding 5-6%.

It is impossible to meet the increased requirements with respect to the accuracy of accelerometers without reorganizing and improving the calibration and checking of these instruments.

The experience gained during many years shows that the best method of ensuring uniformity of measurements consists in establishing and reproducing with the highest possible accuracy measuring units in metrological institutes and transferring the values of these units to industrial measuring instruments by means of reference instruments. The method of transferring accurate units from the reference to the industrial instruments should be specified in All-Union standardization documents (instructions, specifications), approved by the Committee of Standards, Measures and Measuring Instruments. A centralized supervision should be organized over the accuracy of accelerometer readings.

This work will be most effective if it is conducted not only by metrological institutions, but also by service laboratories which have gained considerable experience in the sphere of accelerometry.

In view of the fact that in the sphere of dynamic measurements metrological concepts have not acquired a uniform interpretation, we shall first determine the meaning we ascribe to some of these concepts.

Depending on the behavior of the measured quantity with respect to time we divide measurements into two groups: the static and the dynamic, and we divide the instruments which measure these two quantities into the same groups. In static measurements the measured quantity is assumed to remain constant during measurements. Hence, measurements of a constant parameter in a dynamic process; for instance, peak or effective values or some other value of a periodically changing quantity we consider to be static measurements.

Dynamic measurements are characterized by the measured quantity changing its value during measurement, and it is determined in a certain known scale as a function of time. In conducting dynamic measurements one gets

* In the nature of a discussion – Editorial Board.

either a continuous (in the form of graphs and diagrams) or discrete series of consecutive values of the variable expressed in established units, and corresponding values of time.

In contrast to static measurements, in which only one quantity is measured, dynamic measurements involve a simultaneous determination of two quantities connected by a functional relation.

This peculiarity of dynamic measurements led to the appearance of the concept of a dynamic error.

The readings of dynamic-measuring instruments depend not only on the value of the quantity but also on the nature of its variations with time. Dynamic errors evaluate quantitatively the degree to which the curve recorded by the instrument deviates from the actual curve depicting the variable quantity. In checking dynamic measuring instruments the curve recorded by a reference instrument is taken as the actual curve of the variable. The curve recorded by a dynamic-measuring instrument may be distorted both with respect to the Y-axis and the X-axis. The first type of distortions are known as amplitude errors and the second type as phase errors; the combined effect of both of them represents the dynamic error.

A convenient concept of dynamic errors used in the design of measuring instruments, which represents them as a difference of readings of an instrument when measuring the same quantity, is of little use in the checking technique. Such a definition does not characterize the error in the instrument readings but the variation of its sensitivity. The sensitivity of an accelerometer or one of its units (transducer, amplifier, output device, etc.) is described by the ratio of its output to its input signal if the latter is sinusoidal. If the sensitivity of the instrument does not drop to zero when the frequency of the input signal approaches zero, it is said that the instrument possesses a zero frequency characteristic. If the sensitivity of a linear converter for a given accuracy does not depend on frequency in a certain frequency range, the mean value of its sensitivity is said to be the calibration coefficient for that range.

Let us now examine the problems connected with the calibration of accelerometers intended to ensure the accuracy of their readings.

At present many plants have specialized test laboratories. The task of these laboratories consists in conducting under specific conditions measurements of given quantities with a given accuracy. In view of the lack of model measuring instruments which could be used for the above task, laboratories developed the required measuring equipment, test and calibrate it, and use it for measuring the required quantities and evaluating the accuracy of the measurement results. The same experts under these conditions act as instrument makers, metrologists and users of the measuring equipments. They can, to a varying degree, take into account the design peculiarities of their equipment and the effect of various factors on the readings. Comprehensive computation and elimination of errors depend in this case on the complexity of the problem and the qualifications of the experimenters.

That kind of activity aimed at constructing measuring instruments in new spheres of measurement should not and cannot be controlled in any way.

In order to raise the efficiency of this progressive activity the test laboratories should be freed of the necessity to develop and make instruments which without being new in their design are not mass produced.

When we refer to the methods and means of ensuring accurate readings of instruments for dynamic measurements, and in particular for accelerometers, we have not in mind the above instances of so-called non-standard measuremements, but instances which represent the overwhelming majority of measurements in which these instruments are used by persons who have not taken part in their design, production or calibration, i.e., when mass produced instruments with standard characteristics are being used.

The persons using such instruments should be able to determine from their readings and basic characteristics the actual value of the measured quantity and the accuracy of the measurement.

Not all the accelerators available at the present time are designed for dynamic measurements of acceleration; some of them are intended for static measurement, for instance, accelerometers for measuring peak or mean values of oscillatory acceleration.

There are accelerometers whose readings are calibrated directly in units of acceleration, but there are others calibrated in conventional units (scale divisions or millivolts).

Instruments with nonuniform scales are permissible for static measurement.

Nonuniform scales in dynamic measuring instruments cannot provide in practice an evaluation of the error of measurements made by such nonlinear instruments.

Hence the linearity of the scale is one of the most important conditions which must be met by instruments of this type; moreover, this condition applies not only to the scale of the measured quantity but also to the time scale.

The characteristics of mass produced accelerometers must be determined in testing each type of instrument, and the calibration and checking of these instruments will consist only in determining the accuracy and correctness of readings within the limits of the set operating frequency range. For linear scale accelerometers the calibration coefficient may be taken as a constant of the instrument and determined as the mean value of its sensitivity in the operating frequency range. The accuracy of an instrument for dynamic measurements is characterized not only by the error due to the instability of its readings, indications and the method of calibration, but also by the dynamic error which is due to the calibration coefficient not coinciding with the sensitivity of the instrument in different parts of the operating frequency range. Hence in standardizing the requirements for the accuracy of accelerometers, in addition to an error tolerance one should also indicate the range to which each of the component errors should apply.

The calibration of accelerometers for a given frequency and amplitude of sinusoidal oscillations impressed on the instrument by means of a vibrator is most commonly used. But the calibration of an accelerometer with a continuous reading and a reading of maximum values of acceleration may also be attained by means of a controlled excitation of a short duration, whose components with respect to amplitude and frequency are within the operating range of the instrument.

In both instances it is necessary to have for calibration purposes a vibrator which meets certain requirements, is equipped with means for direct or indirect measurement of acceleration which are impressed on the accelerometer being calibrated, and with means of recording or measuring the output signal of the instrument, if it is not already equipped with all these means.

The vibrator requirements are determined by a method similar to the one used for measuring the acceleration impressed on the accelerometer.

The vibrator may consist of an accelerometer stand which is rotated with respect to the force of gravity (a rotating calibration platform), a centrifuge, electrodynamic vibrator, physical pendulum or an anvil of a ballistic pendulum. There are other types of vibrators as well. The rotating platform and centrifuge are used for calibrating at zero frequency. Electrodynamic vibrators are used for calibrating at stable-state sinusoidal vibrations.

The requirements of a vibrator become considerably less exacting if the acceleration impressed on the accelerometer under test is measured by means of a reference accelerometer instead of an indirect method. In this method readings of a reference accelerometer are compared with those of the accelerometer under test, when both instruments are subjected to the same acceleration. The vibrator is only required to impress on the reference and tested accelerometers the same acceleration in a given range of frequencies and amplitudes. The reference accelerometer may be incorporated in the vibrator or made in the form of a portable instrument. It is in principle permissible to use as reference instruments accelerometers of the same construction as the operating models, providing they have a considerably smaller error of operation than the latter type. This can be attained if stable instruments are chosen and carefully calibrated by one of the indirect methods.

However, it is not advisable to have the same variety of reference accelerometers as operational ones, since the latter differ by the use they are intended for, but a reference accelerometer is only designed to measure accurately peak values of acceleration which the vibrator induces in the instrument under test.

Calibration of accelerometers by the comparison method not only simplifies the determination of the actual acceleration, but also that of the instrument calibration accuracy, since the accuracy of the reference instrument is determined when it is certified.

In order to introduce a testing method which is the most convenient, reliable and productive the following problems have to be solved.

1. To establish the technical requirements for a reference accelerometer in various measurement and frequency ranges.

2. To develop model designs of reference accelerometers and organize their mass production.

3. To develop the necessary methods and equipment for certifying reference accelerometers in the metrological institutions and for their check testing in test laboratories.

4. To develop model designs of vibrators intended for calibration purposes and organize their mass production.

5. To develop specification stipulating the technique of calibrating accelerometers by the comparison method.

As a temporary method until the complete solution of the above problems, it seems possible to establish a certain order in providing uniform measurements of acceleration by standardizing several most promising methods of calibrating accelerometers based on an indirect measurement of the acceleration impressed on the instrument under calibration.

It should be noted here that the accuracy of indirect measurements of acceleration depends not only on the accuracy of the direct measurements of quantities related to acceleration by a known equation, but also on the degree to which the so-called influencing quantities have been discovered and taken into account, i.e., those quantities which affect the results, but are not measurable.

Indirect measurements carried out by the same standard method, but by means of equipment of varying designs under different conditions, may contain different systematic errors, depending on the degree to which the influencing quantities have been investigated and accounted for.

In order to introduce uniformity in the finding and elimination of these systematic errors, the devices for calibrating accelerometers by standard methods should be compulsorily certified in metrological institutions.

Taking into consideration that the readings of an accelerometer fixed to a vibrator may differ for the same method of operation but different methods of fixing the instrument to the vibrator, it is necessary to specify not only the methods of calibration, but also the methods and means used in fixing them during calibration and in current use.

In standardizing the best calibration methods, both Soviet and foreign practice should be taken into account. It is timely to note that in the USA the following standard methods for calibrating vibrometric (including accelerometric) equipment have been adopted: the rotating platform, centrifugal, electrodynamic vibrator, physical pendulum and ballistic pendulum method.

Persons with considerable experience in the sphere of vibrometry using high quality apparatus have attained by these methods calibrating accuracy of ± 1% at frequencies up to 900 cps, of ±2% up to 2000 cps, and of ±5% at frequencies above 2000 cps.

In summarizing it should be noted that the problem of ensuring uniformity in the acceleration measurement results and in other parameters of movement will only be properly solved when for measuring these quantities model measuring instruments of general use are provided for all the main measuring and frequency ranges, i.e., when order is established in this branch of the instrument-making industry.

The development and manufacture of model instruments of general use for measuring parameters of movement is a long-overdue necessity.

These instruments should embody the experience accumulated in the development of special purpose apparatus, and should also make use of the economically advantageous principle of unit constructions.

The marketing of model measuring apparatus of general use will reduce to a minimum the very uneconomical "original" development in this sphere of measurements and will reduce them in many cases to the design of auxiliary equipment for the model apparatus.

The model apparatus in all the stages of its development should pass strict state testing in metrological institutions; simultaneously with this testing it will be possible to establish the most rational methods and equipment for the calibration and periodic testing of this apparatus.

INDUCTION TRANSDUCER FOR MEASURING RAPIDLY CHANGING PRESSURES

S. M. Gugel'

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 20-21, January, 1961

For investigating the value and nature of pressure variations in a fuel supply system for internal combustion engines we have constructed a high-pressure induction transducer.

Induction transducers have not been used so far for measuring high, rapidly changing pressures and, therefore, the satisfactory results obtained by us in this respect are of some interest.

The main components of the transducer (Fig. 1) consist of two E-shaped cores 9 made of transformer iron. The cores carry coils 10 with 220 turns of 0.2 mm wire. One of the cores is mounted on transducer lid 8 which has two openings, making it possible to vary the distance between the cores during adjustments. The other core is mounted on the magnet-holder 7 which is made dismountable for admitting the transducer coil. In the gap between the cores the magnet coil 5 is placed and connected to diaphragm 4, which is fixed between the fuel receiver 1 and the thrust collar 6.

Hermetic sealing in the high pressure area is provided by copper packing.

After the transducer is assembled the position of the magnet coil is adjusted in such a manner that the gaps between it and the lower cores are equal. This is attained by a displacement of the upper and lower cores. The upper core is displaced by means of packing, and the lower by the adjusting screws 11. Equal gaps provide equal coil currents, and owing to their opposite direction a zero reading on the indicator (oscilloscope or milliammeter).

The reluctance of an open-circuited magnetic core is:

$$R_\mu = \frac{l}{\mu S} + \frac{l_0}{\mu_0 S_0}$$

where R_μ is the reluctance; l, S, μ are the length, area of the cross section perpendicular to the flux, and permeability of the core respectively; l_0, S_0, μ_0 are the corresponding values for the air gap.

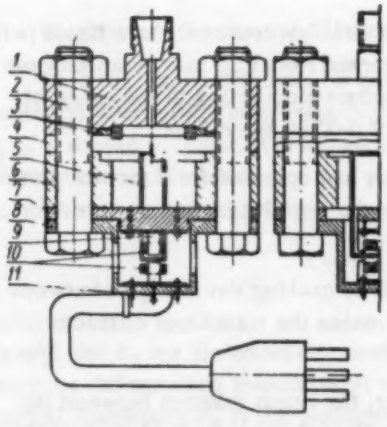

Fig. 1. Schematic of a high-pressure induction transducer. 1) Fuel receiver; 2) bolt with a nut; 3) packing; 4) diaphragm; 5) magnet coil; 6) thrust collar; 7) magnet holder; 8) lid; 9) core; 10) coil; 11) adjusting screw.

The first term in the right-hand side of the equation may be neglected, since $\mu >> \mu_0$. Since μ_0 and S_0 are constant for this construction of the transducer, the permeability is a function of the air gap, $R_\mu \simeq cl_0$, where $c = 1/\mu_0 S_0$ is a constant for a given construction of the transducer.

The variation of air-gap l_0 is caused by the elastic deformation of the diaphragm which is subjected to the fuel pressure and in bending displaces the magnet coil which is rigidly connected to it. When the coil is deflected from its zero (neutral) position, the transducer circuit will pass a current whose value and direction will depend on the bending of the diaphragm, i.e., on the pressure in the pipeline.

The transducer works in conjunction with the strain-gauge equipment of the Rostov Institute of Railroad Engineers (designer V. B. Skvarkovskii) which is widely used for investigating various processes by means of induction transducers of appropriate design.

Figure 2 shows the electrical circuit of the single channel instrument used.

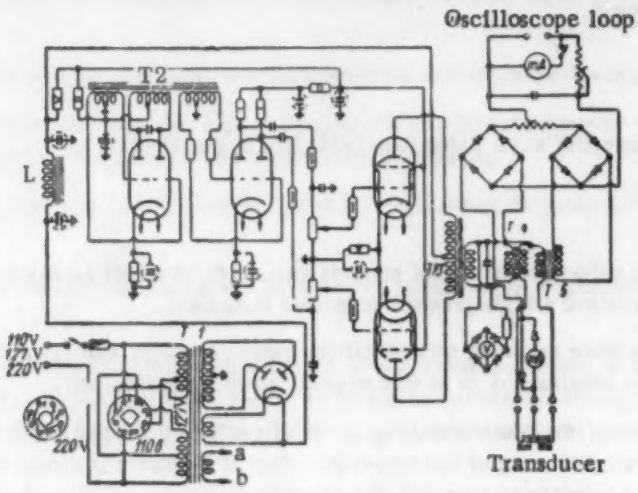

Fig. 2.

In order to determine the efficiency of the transducers, they were tested dynamically under working conditions with a maximum load for 5 hours. In these tests their hermetic seal and zero stability were also checked. Next, the natural resonance frequency of each transducer was determined as well as its heating-up time. Natural oscillations of the diaphragm were set up by hitting it and then recorded on an oscillograph side by side with time markers of 50 and 500 cps. Tests have shown that the minimum frequency of the transducers' natural oscillations of 300 cps considerably exceeds the frequency of the process under test, and thus prevents the transducers introducing distortions in the curve of the recorded process.

The heating-up tests showed that during the heating up of the complete equipment (voltage stabilizer, strain-gauge instrument and transducer) the transducer supply current and voltage and its output signal current remained unstable for 90-120 minutes. This is the minimum time required to make the equipment ready for testing.

When a cold transducer is connected to a warmed-up equipment its readings stabilize in 5-10 minutes. This shows that in working with several transducers and a single strain-gauge equipment measurements can only be made 5-10 minutes after replacing a transducer.

The above conclusions were used in calibrating transducers of reference weighted-piston,3000 kg-wt/cm^2, manometers according to the method described for calibrating reference manometers.

The largest referred measurement error calculated on the basis of calibrations repeated three times (with the pressure being raised and dropped in the system of the reference manometer from 0 to maximum pressure and vice versa, in intervals of 50 kg-wt/cm^2) amounted to 1-1,5% for transducers operating in the range of 0-800 kg-wt/cm^2, and to 1,5-2,5% for transducers operating in the range of 0-1200 kg-wt/cm^2.

A check test by means of a reference manometer after the transducers had operated for 6 months provided similar results. A check test under similar conditions on the test rack after the transducers had operated for one year provided a complete coincidence of all the oscillograph curves.

It should be noted that the pressure measuring range can be increased by making the two gaps between the moving coil and the cores considerably different from each other, but this makes the transducer characteristics non-linear and increases their sensitivity.

If the gaps are changed by more than 0,4-0,5 of their original setting, the linear relation between the transducer output signal current and pressure is disrupted, but this does not affect the accuracy of the transducer readings.

RELATION OF THE REDUCTION RATIO OF PISTON DYNAMOMETER SYSTEMS TO THEIR LOADING

K. I. Perchikhin

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 21-22,
January, 1961

The reduction ratio of piston dynamometer systems, consisting of a power and a manometric piston only hydraulically coupled is determined by the ratio of the referred areas of the power and manometric pistons.

The referred area of a piston varies owing to deformations of the piston and cylinder elements under the effect of pressure. The relation of the referred area to pressure has been derived in [1] and experimentally confirmed in [2, 3].

In a general form the referred area of a measuring piston is:

$$F = \pi R^2 (1 + a + \lambda P), \tag{1}$$

where R is the piston radius; α is the relative gap equal to the ratio of the difference between the cylinder and piston diameters and the piston diameter; λ is a coefficient characterizing the effect of deformations: P is the pressure on the piston butt.

The reduction ratio of a dynamometer system is:

$$i = \left(\frac{R}{r}\right)^2 \left(\frac{1+\alpha+\lambda P}{1+\alpha_1+\lambda_1 P_1}\right),$$

and hence, the relation of the reduction ratio to the value of the reproduced force can be expressed by the equation:

$$i = \left(\frac{R}{r}\right)^2 \left[1 + (\alpha - \alpha_1) + (\lambda - \lambda_1)\frac{N+G}{\pi R^2}\right], \tag{2}$$

where R and r are the radii of the power and manometric pistons respectively; N is the value of the reproduced force; G is the weight of the construction corresponding to the loading of the power piston for a zero reading.

Notations with subscript "1" correspond to the manometric piston and cylinder.

Deformation coefficients for a simple piston and cylinder, a differential piston and simple cylinder, and a simple cylinder with a bush subjected to even-counter pressure, are all given in [1]. For a construction consisting of a simple cylinder with a bush subjected to a counter-pressure varying along its generating line [4] the deformation coefficient is:

$$\lambda = \frac{1}{E}\left[3\mu - 1 + \frac{E}{E_2}\left(-\frac{P_2}{P}\cdot\frac{2}{1-t^2} + \frac{1+t^2}{1-t^2} + \mu_2\right)\right], \tag{3}$$

where E and E_2 are the elasticity moduli of the piston and bush respectively; μ and μ_2 are the coefficients of transverse deformation respectively; t is the relative thickness of the bush wall (the ratio of its internal to its external diameter); P_2 is the pressure of the liquid fed from the external surface of the bush.

According to (2) measurements can be corrected for the effect of loading on the reduction ratio. If required these corrections may be accounted for directly in adjusting the loading, thus the measurement results will be corrected automatically.

It follows from (2) that if condition $\lambda = \lambda_1$ is kept, the reduction ratio will be independent of loading (i = const). This condition may be met by selecting appropriate elastic constants for the materials and cross sections of cylinders (bushes).

SUMMARY

The systematic error due to the effect of loading on the reduction ratio of systems may be accounted for, and even systems of piston scales and dynamometers produced which preserve a constant reduction ratio over the whole measuring range.

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THERMOTECHNICAL MEASUREMENTS

COMPLEX OF METROLOGICAL WORK ON ESTABLISHING METHODS AND APPARATUS FOR PRECISE MEASUREMENTS OF HIGH TEMPERATURES

A. N. Gordov, K. S. Izrailov, V. V. Kandyba, I. I. Kirenkov, V. A. Kovalevskii, É. A. Lapina, V. E. Finkel'shtein, and N. N. Érgardt

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 22-25, January, 1961

Requirements for accuracy and range in high temperature measurements which have risen in recent years in various branches of industry and new technology necessitate a radical reconstruction of the whole metrological system in the measurement of high temperatures, as well as the development of new standard and reference instruments based on the latest achievements of science and precision instrument making. In this connection the institutes of the Committee of Standards, Measures and Measuring Instruments, namely, the D. I. Mendeleev VNIIM (All-Union Scientific Research Institute of Metrology) and the KhGIMIP (the Khar'kov State Institute of Measures and Measuring Instruments), have mapped out a complex of metrological work on establishing new high-precision standards and reference instruments for temperatures up to 1000°C.

This enormous work was completed in 1960. It represents a single complex of metrological investigations necessary for ensuring technical progress in the branches of industry and new technology which make use of high temperatures.

As a result of this work a metrological foundation has been laid for providing the required accuracy and extending the range of high temperature measurements, new instruments and devices have been made and put into use for precise measurements at high temperatures and for ensuring uniformity of such measurements.

The work was conducted in four basic aspects, gas thermometry, thermoelectric pyrometry, optical and visual pyrometry, and objective pyrometry (photoelectric and radiation), which comprised the following nine sections:

more precise determinations by means of gas thermometer methods of the deviations in the International Practical Temperature Scale from the thermodynamic scale;

development and introduction of calibration methods for highly stable reference and industrial thermocouples at temperatures up to 1800°C;

production of high-precision luminous optical pyrometers for use as standard and reference instruments in a wide temperature range;

development of methods for calibrating and checking precision industrial pyrometers at temperatures up to 10000°C;

development of methods of objective spectropyrometry and production of precision equipment for calibrating at high temperatures with the utmost precision;

reproduction of luminance and color temperature scales by objective methods;

establishment of a group of highly stable radiators to be used as standard and reference measures for calibration and checking of luminous and color pyrometers;

production and bringing into use of radiators and devices for calibrating and checking reference and industrial radiation pyrometers;

production and bringing into use high precision spectropyrometers for measuring temperatures by means of infrared radiations.

The basic metrological task of raising the accuracy of reproducing the International Practical Temperature Scale by a more precise definition of its deviations from the thermodynamic scale was accomplished by the establishment of unique gas thermometers, and by carrying out simultaneously and independently on two installations a large number of precision measurements, which provided for the first time our own national data in this sphere of metrology. In comparison with similar data obtained in recent years by other national metrological laboratories (F. G. R., Japan), the data obtained in the USSR solves the most important problem in modern metrology – namely, a more precise definition of the practical temperature scale which serves as the basis for all temperature measurements [1-5].

The plotting of a temperature scale in the high temperature range was accomplished on the basis of objective spectropyrometric methods which are new in their principle of operation. The precision SPK sets developed for this purpose have provided a reliable means of conveying the high temperature scale for use in our national economy and have radically raised the accuracy of high temperature measurements, raising it at least tenfold as compared with the best optical pyrometers. Systems now being developed abroad are similar to those previously proposed in the USSR [24], however, the ideas put into practice by the metrological institutes of the USSR [20] provide even more accurate measurements at high temperatures; it is sufficient to state that SPK sets provide temperature measurements at the "point of gold" (1063°C) with a quadratic mean error of the order of 0.05°C [19, 21, 22, 23, 25, 26, 27, 34-39].

The production of the SPK sets has put Soviet metrology far ahead of other countries in the sphere of high temperature measurements.

In order to convey the values of a temperature scale, highly stable standard and reference instruments and standards of temperature are required. Such standards have been provided by tested out and certified special temperature lamps which are calibrated in luminance and color temperature scales; for the first time state standards have been established for preserving color temperature scales [28, 42, 44].

The high precision calibration of these lamps by means of the SPK sets ensures the required higher accuracy in calibrating and checking various types of optical pyrometers. The metrological work carried out in calibrating these lamps for color temperatures has provided a basis for the development in the USSR of color pyrometry which caters to the needs of our industry [30, 31, 32].

In the technique of high temperature measurements up to the present we have been lagging in the development and use of new precision equipment for measuring luminance temperatures, since we had not developed our own models of precision optical pyrometers. Industrial optical pyrometers which are used for measuring high temperatures are known to be very inaccurate. Thus, grade 1.5 optical pyrometers type OPPIR have a tolerance at 1000°C up to ± 15°C, and at 2000°C up to ± 30°C. Obviously, such a low accuracy is completely inadequate for many branches of industry and for research in the sphere of new technology. The production of precision grade 0.5 or 0.2 optical pyrometers became, therefore, a pressing task.

In connection with the above task of direct high-precision temperature measurements precision optical pyrometers ÉOP-51 and OP-48 [9, 10] were developed and manufactured. These pyrometers are the first Soviet-made high-precision instruments for high temperature measurements. In their degree of accuracy they correspond to grades 0.5-0.2-0.1.

Pyrometers ÉOP-51 and OP-48 are widely used in research and commercial work and in special organizations of the USSR. One of the ÉOP-51 instruments after detailed investigation has been approved as a working standard. A number of national metrological institutions of socialist countries (Ch. P. R., K. P. D. R, Czechoslovakia, Poland, Bulgaria) are at present basing their work in the sphere of precision high-temperature measurements on pyrometers É OP-51 and OP-48, whose mass production they have assimilated.

The assimilation of ÉOP-51 and OP-48 by the state inspection laboratories of measurement equipment, as well as the assimilation of reference temperature lamps calibrated by means of the SPK and ÉOP sets, has established the required material and technical base of a widespread system for maintaining uniform high temperature measurements on the territory of the USSR.

This system has at present been put into practice in the following way. The international temperature scale is reproduced with the highest possible precision by the VNIIM. The institutes of the Committee of Standards, Measures and Measuring Instruments possess reference optical pyrometers and temperature lamps, which preserve the International Temperature Scale, as well as secondary reference 1st grade optical pyrometers. These instruments serve to calibrate and check 2nd grade optical pyrometers kept at the GKLs (state inspection laboratory) which exist in all the large industrial centers of the country.

The 2nd grade pyrometers and lamps serve for state testing of all industrial optical pyrometers in general use, thus providing the required uniform high temperature measurements in our national economy.

The aggregate of the completed metrological work also included the pressing problem of extending the high temperature range of measurements. New original methods of extending the scale of optical pyrometers from 6000 to 10000°C were worked out theoretically and checked experimentally. These methods have the advantage of not requiring for the calibration and checking of optical pyrometers any high-temperature calibration sources of luminescent temperatures and provide high accuracy in extending the high temperature range [11-18].

As a result of this work the requirements of new technology for accurate measurement of temperatures up to 10000°C have been satisfied.

Side by side with optical pyrometry radiation pyrometry has also been satisfactorily developed. The VNIIM and KhGIMIP have produced unique high-power "black body" radiators with a stable operation up to 2500°C, which in conjunction with pyrometers ÉOP-51 provide maximum precision for calibrating reference radiation pyrometers.

For checking commercial radiation pyrometers the mass-produced new optical sets type URP are now used. They have a considerably higher temperature range (up to 1800 and 2500°C) than the nickel plate instruments. The URP sets are now widely used by the GKLs, instrument-making plants and factory laboratories; they have also been supplied to metrological laboratories of a number of socialist countries. This new equipment has provided a radical improvement in the accuracy of calibrating radiation pyrometers at high temperatures [46, 47, 51, 52, 53].

The development of industrial pyrometry, and in the first place of the pyrometry of spectral relations, (color pyrometry) made it necessary to produce reference instruments for measuring temperature by means of infrared radiations.

In order to meet these requirements of the measurement techniques, new precision spectropyrometers types IKP-57 and reference sources of infrared radiations have been produced. The IKP-57 pyrometers, in the same manner as the objective spectropyrometric sets SPK, provide temperature measurements of infrared radiation with extremely high accuracy; the IKP-57 pyrometers surpass in their metrological qualities the known infrared pyrometers developed in foreign laboratories.

The production of these instruments and reference radiators ensures the development of industrial infrared pyrometry, which is a most promising sphere of measurement technology [55, 56].

It is especially important to attain high precision reference instruments for measuring temperatures in industrial establishments. An important part is played in this respect by the knowledge of the coefficient of black radiation (radiation capacity) of actual objects. Only if the degree of "blackness" is taken into account is it possible to measure with high precision the actual temperatures of the objects.

The methods of modulation reflectometry developed in our country [33, 54] make it possible to determine systematically the coefficient of black radiation of actual bodies, thus ensuring the conveyance of the International Temperature Scale to industry with the highest possible precision.

One of the most important problems in industrial pyrometry is the establishment of a metrological base for a wide industrial application of stable high-temperature thermocouples, which are especially required for

measuring temperatures in metallurgical processes, and in the first place in the production of steel and heat resistant alloys.

The development of methods and apparatus for calibrating highly stable thermocouples, and their provision with model calibration tables, have supplied the required metrological foundation for mass production by our own instrument-making industry and wide use by our industry of thermocouples measuring up to 1800°C.

The joint solution of all these problems, the establishment and assimilation of new methods for precision high temperature measurements, has been accomplished for the first time. A metrological foundation has been laid for a radical improvement in the accuracy of high temperature measurements.

As a result of the above work we have attained and in several spheres outstripped the world level in metrological research, thus placing Soviet metrology in the sphere of high temperature measurements in the first place in the world.

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ELECTRICAL MEASUREMENTS

HIGH-SPEED COMPENSATION INSTRUMENTS

P. V. Novitskii

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January, 1961

Self-balancing compensation bridge measuring circuits are widely used in measurement technique, especially in automatic measurements. Their important drawback consists in the low operating speed due to the balancing being performed, as a rule, by a variable wire resistor (slide wire) with a mechanical drive by an electrical motor. Its speed of operation can be raised hundreds and thousands of times only if an electronically controlled resistance is used which is operated directly by the electrical current (without using a motor). Such a resistance must have a linear relation to the control current or voltage and must remain stable with time.

When various controllable resistances (magnetized coils, piezoelectric devices, electron tubes, crystal diodes, transistors, etc.), were examined, it was found that the above requirements are best met by semiconductor germanium or copper oxide diodes. In fact, the resistance of a semi-conductor diode varies with the current $I_{=}$ flowing through it, as indicated by curve in Fig. 1. Moreover, the dynamic conductance of the diode up to a certain increase in the current is a rising linear function of the current.

If four diodes are connected in a bridge circuit and one of its diagonals is fed from an external source by a dc controlling current in the conducting direction, the dynamic conductivity of the other diagonal for the controlled alternating current will be proportional to the value of the controlling current. In order to preserve the linearity of this controlled conductance for the alternating current, and to preserve the linear relation of the conductance in the ac circuit to the controlling direct current, the alternating voltage in the controlled circuit must not exceed 40 mv for copper oxide, or 100 mv for germanium diodes. This is due to the fact that when diodes operate over small sections 1 or 2 of their characteristic (Fig. 1), a small rise in the resistance of a pair of diagonally opposite diodes (for which the controlled and controlling currents are in opposite directions) is compensated by a similar decrease in the resistance of the other pair (for which the two currents are in the same direction). If it is required to control a circuit with a large alternating voltage each arm of the bridge must contain a correspondingly large number of diodes.

Thus, this diode bridge is in fact a linear controlled resistance without inertia, whose conductivity is proportional to the controlling current and can be used for automatic electronic balancing of various measuring circuits [1]. By use of it, it is possible to design compensating instruments for measuring instantaneous values of current and voltage, high-speed self-balancing bridges for measuring resistance, capacitance and inductance. It also opens up possibilities for designing high-speed compensation instruments for measuring nonelectric quantities by means of inductive, capacitative or resistive transducers. Moreover, it is possible to use this electronically controlled resistor not only in instruments with amplitude modulation, but also in those with frequency or phase modulation, where the controlled resistance can be used for regulating the frequency or phase of the carrier voltage.

A certain disadvantage of the electrical control of the compensation resistance as compared with its mechanical control consists in the former not providing, as the mechanical control does, a mechanical displacement which can be used directly for a read-out or recording. In the case of the electrical control this function can be performed by the controlling direct current. However, in case of an oscillographic recording of high-speed phenomena, or tape recording of measurement results, or their transmission over a telemetering channel, the

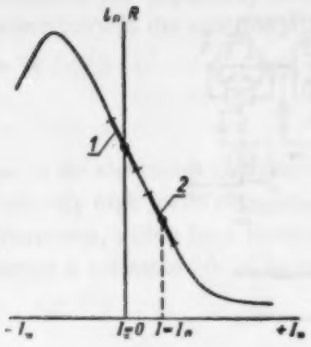

Fig. 1.

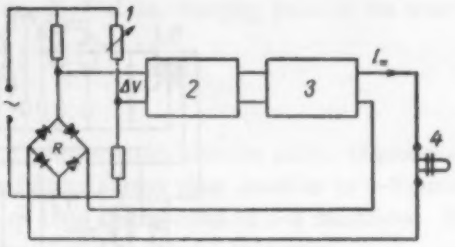

Fig. 2.

presentation of the compensating variable in the form of a direct current is more advantageous than a mechanical displacement.

Another disadvantage of a semiconductor controlled resistance consists in its considerable sensitivity to temperature (of the order of 3-5% per 10°C). In order to eliminate this error the diodes were placed in a miniature thermostat, with the simplest lagging and a heater of 2-3 w connected to a 6.3 v supply through a miniature bimetallic regulator (breaker). Thus, by using the power consumed by a normal electronic tube heater circuit the temperature of the diodes was continuously maintained at a constant level (for instance, at 35 or 45°C with an error of ± 0.3°C), reducing the error due to temperature to fractions of 1%.

As an example of the application of the above controlled resistance to instruments with high-speed automatic balancing for measuring electrical and nonelectrical quantities we show in Fig. 2 a block-schematic of a high-speed bridge with automatic balancing and a transducer in the form of a variable resistance. Here transducer 1 of the measured variable is connected to the bridge whose opposite arm is formed by the controlled resistance R, which consists of four semiconductor diodes connected in a bridge circuit. Voltage ΔV is fed from the measuring diagonal of the bridge through ac amplifier 2 to the phase-sensitive demodulator 3. The direct current $I_=$ from the output of the demodulator is used for controlling resistance R and brings the bridge to a near-balanced condition; at the same time this current is used to operate an oscillographic galvanometer 4.

Since the conductance of the diode bridge is a linear function of the controlling current $I_=$, the instrument scale can be calibrated in units of resistance variation of transducer 1.

In order to provide the instrument with the maximum speed of operation an amplitude demodulator with a memory and a reset [2, 3] was used for the phase-sensitive demodulator 3.

The operating speed of this instrument was studied by means of its output current oscillograms for a carrier frequency of 1200 cps and instantaneous variations in the transducer 1 resistance at the rate of 150 cps. Instantaneous variations in the transducer resistance were attained by a periodic switching-in of a shunting resistance through the contacts of a polarized relay. It was found that the operating speed of such a self-balancing bridge is determined by that of the demodulator, and since the demodulator memory circuit has not sufficient time to attain a stable reading during the first period of the carrier frequency, the bridge becomes balanced only during the second period. Thus, the balancing time of the bridge for a carrier frequency of 1200 cps is about 0.001 sec. However, the operating condition of this circuit at a maximum possible speed is very critical with respect to the instability of its servosystem due to self-oscillations. In order to provide a sufficient margin of stability it is desirable to limit the operating speed to 2-3 periods of the carrier frequency, designing the phase-sensitive demodulator so that its memory circuit attains the required reading only after 2-3 periods of the carrier frequency.

In this case the whole of the servosystem has only one time constant due to the large lag of the demodulator, and the depth of feed-back can be made arbitrarily large without endangering the stability of the system. The speed of operation for a carrier frequency of the order of 1000 cps will then amount to 0.002-0.003 sec.

Instruments with capacitative or inductive transducers can also be designed on this principle.

Figure 3 shows a circuit of an instrument operating with a differential inductive transducer. Here the transducer is coupled by means of a compensating measuring circuit similar to the one previously proposed by the author for instruments with mechanical balancing [4]. The differential inductive transducer IT is connected

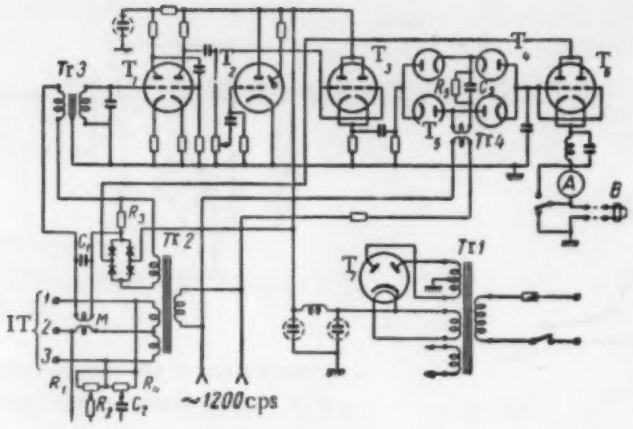

Fig. 3.

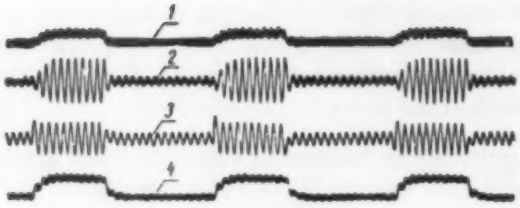

Fig. 4.

to terminals 1, 2, and 3, and forms together with the two half windings of the supply transformer Tr2 an unbalanced measuring circuit. Variable resistors R_1 and R_4 together with resistor R_2 and capacitor C_2 serve to balance the circuit when the measured quantity is equal to zero.

It is known that the output current of an inductive or capacitative transducer is displaced in phase with respect to the supply voltage by almost a quarter of a period. Hence, in order to obtain a voltage in phase with the supply voltage the output of the bridge is connected to a mutual inductance coil M whose output voltage is displaced by a quarter of a period with respect to the current in its primary winding. For an accurate correction of the phase-shift, capacitor C_1 is used which is adjusted experimentally. Thus, we obtain at the output of the measuring circuit (across the secondary winding of coil M) a voltage proportional to the measured quantity and in phase with the supply voltage.

This measured voltage is balanced by the voltage of the compensating circuit,which is fed from the same transformer Tr2 and consists of a controlled diode bridge and resistor R_3. Since the conductance of the diode bridge is proportional to the controlling direct current, the compensating carrier frequency voltage obtained from resistor R_3 is also proportional to this current.

The difference between the measured and compensating voltages (the unbalanced voltage) is fed through transformer Tr3 to the amplifier input. The amplifier consists of two voltage amplifying stages (T_1 – 6N2P), an ac cathode follower (T_3 – 6N1P), a ring demodulator with a memory and reset (T_4 and T_5 – 6Kh2P), and a dc cathode follower (T_6 – 6N5P), in whose cathode circuit instrument A is connected for static measurements or an oscillographic galvanometer B for recording, and whose anode circuit is fed from the controlling diode bridge. For preliminary balancing of the measuring circuit by means of resistors R_1 and R_4 the magic eye indicator (T_2 – 6E1P) is used. The ring demodulator is commutated from a peak transformer Tr4.

An oscillogram (Fig. 4) characterizes the work of this instrument, curve 1 represents the direct current in the diode bridge, curve 2 – the compensating carrier voltage of 1200 cps which is obtained from resistor R_3, curve 3 – the voltage across the inductive transducer bridge, and curve 4 – the output current of the instrument.

The inductive transducers were fed by rectangular pulses at a frequency of 50 cps. The transient process due to the inertia of the transducers ends, as it will be seen from curve 3, in one half-period of the carrier frequency, after which the amplitude across the inductive transducer bridge remains constant. The output current of the instrument which controls the compensating circuit grows gradually owing to the lag in the demodulator and only reaches a stable value after 2-3 periods of the carrier frequency, which is clearly seen from curve 4. Owing to this, the compensating voltage (curve 2) also grows gradually and a balanced condition is only reached after 2-3 periods. Such a demodulator lag is required, as has already been pointed out, in order to make the servo-system stable for a relatively large depth of feed-back. This lagging is determined by the ratio between

values of the resistor and capacitor, since for a given pulse of the commutating voltage, resistor R_5 limits the quantity of electricity in the commutating current pulse, and hence also in the charging pulse of the memory capacitor C_3.

SUMMARY

The use of an electronic controlled resistance for balancing compensation circuits makes it possible to construct extremely high speed compensation instruments, whose full balancing time amounts to 2-3 periods of the carrier frequency, which for a carrier frequency of the order of 1000 cps amounts to 2-3 microsec. If the carrier frequency is raised to 10-30 kc the operating time can be reduced to 0.3-0.1 microsec.

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TRANSISTORIZED FREQUENCY METER

V. I. Safonov and I. N. Ivanov

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A transistorized frequency meter is briefly described in this article. The frequency meter employs a capacitative method of measuring frequency based on a periodic charging and discharging of a capacitor with a direct measurement of the discharged current, which is proportional to the frequency. This method provides a relative simplicity of the device and makes it possible to use the frequency meter over a wide range of frequencies with a sufficient accuracy and linearity. The measurement results do not depend on the shape or value of the input voltage, providing amplitude limitation is used. Such frequency meters can be used for measuring frequency, counting elementary particles in physics, in telemetering and control systems, in tachometers and in various other applications when nonelectrical quantities are measured by electrical means.

The frequency meter here described is designed to work in the range of 5 cps to 10 kc. The input voltage may vary over a wide range from 3 mv to 1.5 v. If a high voltage signal is likely to be fed to its input, arrangements must be made for its attenuation. The frequency meter operates from 120-220 v ac mains. For supply voltage variations of ± 10% the instrument error does not exceed ±0.1%. Its nonlinearity (together with the associated measuring instrument PS-1) in the range of 5-100 cps amounts to 1%. The instrument can operate with an ambient temperature up to 80°C. When this temperature was changed from +20 to +70°C, the deviation in the reading of the model instrument amounted to 0.2%, i.e., 0.04% per 10°C. The mains power consumed by the instrument is 5 w.

For checking the instrument in the range of 5-100 cps provision is made for feeding to its input a control signal of 50 cps obtained from a special winding of the mains transformer.

The measured frequency signal (Fig. 1) is fed to the first voltage preamplifier, which uses transistors type P13A connected in a common emitter circuit. From the first stage the signal is fed to the second stage, which operates in an overloaded condition and provides amplitude-limited, almost rectangular pulses fed to the commutating stage of the frequency meter. The commutating stage, like the other stages, uses type P13A transistors and operates as a relay switch. In its normal condition transistor T_3 is conducting and the voltage across the measuring capacity is at a minimum (almost 20 mv). When a positive pulse is received from the preceding

stage, T_3 becomes blocked and the measuring capacitor C_m is charged up to the voltage of the reference stabilitron, which fixes the maximum charging voltage.

In a general case the mean current flowing through the instrument is proportional to the voltage across the capacitor and is a complex function of frequency. Thus, in the simplest case when capacitor C is charged through resistor r up to voltage U and then discharged through the same resistance, the mean current flowing through the instrument is:

$$I_m = CUf \frac{1-e^{-\frac{1}{2f\tau}}}{1+e^{-\frac{1}{2f\tau}}}. \qquad (1)$$

where f is the number of charges and discharges per second; $\tau = rC$.

The resistance of the current measuring device can be neglected.

It will be seen from (1) that in order to obtain a linear relation between the current and frequency, i.e., in order to have $I_m = CUf$ it is necessary that $e^{-1/2f\tau} \ll 1$.

Let us now determine the deviation of the real values of the current from linearity.

$$\rho = \frac{CUf - CUf\frac{1-e^{-\frac{1}{2f\tau}}}{1+e^{-\frac{1}{2f\tau}}}}{CUf}.$$

The nature of the relation $\rho = \varphi(f\tau)$ is shown in Fig. 2.

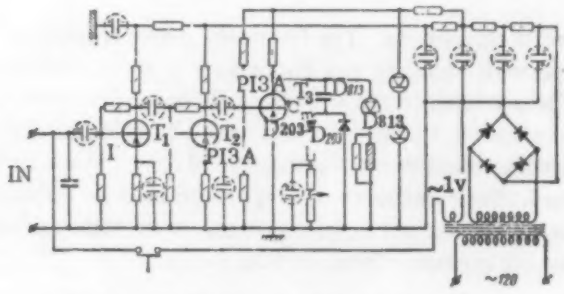

Fig. 1. Schematic of the instrument.

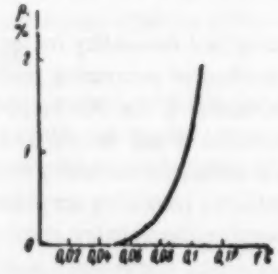

Fig. 2.

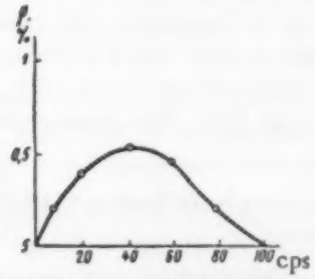

Fig. 3. Distribution of the nonlinearity error along the range of measured frequencies.

For a given instrument nonlinearity tolerance the parameters of the charging and discharging circuit should be chosen by means of equation:

$$f\tau = fCr < (f\tau)^*,$$

where $(f\tau)^*$ is the value of the nonlinearity tolerance.

For smoothing out short-duration current pulses the measuring circuit has a large capacitor and a series resistor. This RC filter limits voltage ripple at the input to the measuring instrument to values suitable for a normal operation of a potentiometer. If a pointer instrument is used the value of this capacitance can be decreased considerably. However, the use of a large

capacitance in a measuring circuit leads to an increased nonlinearity, which is partly eliminated by an additional resistor.

In order to eliminate the effect of supply voltage variations on the frequency meter readings the supply to the commutating transistor is stabilized by means of a semiconductor stabilitron type D813. A change in the ambient temperature produces not only changes in the capacitance but also in the voltage across the stabilitron. Temperature compensation is achieved by connecting in series with the reference stabilitron a thermistor type MMT-9 shunted by a resistor.

The measuring capacitors must have small leakage currents. A sample model arranged as shown in the attached circuit was tested in the range of 5-100 cps. The frequency meter nonlinearity in this range amounted to 0.52%, i.e., ±0.26% (Fig. 3).

In order to be able to use the instrument in other frequency ranges a switch with a set of capacitors is required.

CHECKING THREE-PHASE WATTMETERS

Kh. Shliomovich

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January, 1961

Three-phase wattmeters intended for measuring active or reactive power in a three or four-conductor network are normally checked by comparing them with the readings of 2 or 3 single-phase wattmeters [1]. According to the standard specification [2] this checking should be carried out with the power factor ($\cos\varphi$ or $\sin\varphi$) equal to its nominal value or half that value. The required phase shift is established by means of reference wattmeters whose readings are computed in advance.

In [1] formulas are given for computing the readings of reference wattmeters in terms of current and voltage according to the circuit they are used in. Experience has shown that computing wattmeter readings by means of these formulas is often difficult. This is due to the fixing by specification [2] of the top limits for measuring wattmeters at a value which is not equal to the power determined by the product of the nominal current, voltage and power factor, but corresponds to one of the integer values specified by the standard and nearest to the calculated power.

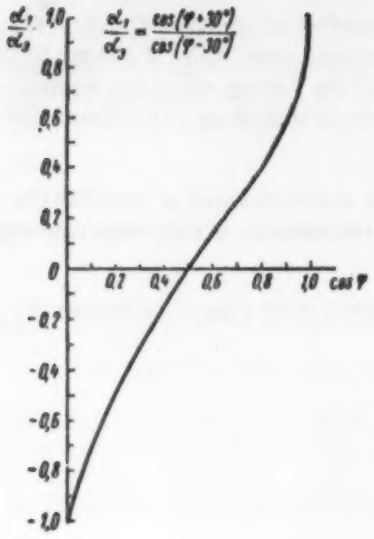
Normally the instrument is checked at the nominal voltage. In such a case for a nominal power factor ($\cos\varphi_n$ or $\sin\varphi_n$) the current I corresponding to the full-scale deflection of the wattmeter will not be the same as the nominal current I_n. Hence, the calculation of the reference single-phase wattmeter readings cannot be made on the basis of nominal values of current and voltage, as recommended in [1], but on the basis of power P_n, which corresponds to the full-scale reading of the wattmeter under test.

As an example let us examine the checking of a three-phase wattmeter designed for measuring active power in a three-conductor network with a nominal power factor differing from 1.

Let the instrument be used for measuring power at a line voltage V_1, current I_n and a power factor $\cos\varphi_n$. The calculated active power is:

$$P_c = \sqrt{3}\, V_c\, I_n \cos\varphi_n.$$

It has already been pointed out that power P_n which corresponds to the full-scale deflection of the instrument approaches the value of P_c, but is not equal to it.



For a most general case let us assume that the wattmeter under test is connected to the mains through instrument current and voltage transformers with a transformation ratio of $K_T = I_n/I_{2n}$ and $K_n = V_n/V_{2n}$ respectively, where I_{2n} and V_{2n} are the nominal values of the current and voltage in the secondary winding, for which the instrument in fact was designed (reference instruments are selected by these values). The power corresponding to the full-scale deflection of the wattmeter will then be equal to:

$$P'_n = \frac{P_n}{K_T K_n}.$$

Let us note that it is sufficient to calculate for the maximum measured power P_n of the instrument under test, since other test points can be obtained by calculating them in the required proportion.

In the case under consideration two reference single-phase wattmeters are used in an Aron-type connection, hence their nominal readings α_1 and α_3 must satisfy the condition:

$$\alpha_1 C_{w1} + \alpha_3 C_{w3} = P'_n$$

In case of an even loading of the phases, when the condition $C_{W1} = C_{W3} = C_W$ must be met, we have:

$$(\alpha_1 + \alpha_3)\ C_w = P'_n$$

Here C_{W1}, C_{W3} and C_W are the wattmeter calibrations.

At the same time, for an even loading of phases the wattmeter readings in terms of $\cos\varphi$ will be determined by the expression:

$$\frac{\alpha_1}{\alpha_3} = \frac{\cos(\varphi + 30°)}{\cos(\varphi - 30°)}.$$

From this equation a graph of $\alpha_1/\alpha_3 = f(\cos\varphi)$ is normally plotted to a scale convenient for calculations. The shape of this curve is shown in the figure attached.

From the above expression one determines:

$$\alpha_1 + \alpha_3 = \frac{P_n}{K_T K_n C_w}$$

and from the graph one finds α_1/α_3, which makes subsequent calculations quite easy.

Irrespective of the required test conditions, the phase shift which corresponds to a given $\cos\varphi$ is determined for a uniform phase load distribution. This operation, which only involves reference wattmeter readings, consists of the following.

The maximum readings of the reference wattmeters for certain constant values of voltage and current correspond to a phase shift of $-30°$ for the first wattmeter ($\alpha_{1\,max}$) and $+30°$ for the second ($\alpha_{3\,max}$), moreover for a normal voltage V_{2n} and current I_{2n} which correspond to P'_n we have:

$$\alpha_{1\,max} = \alpha_{3\,max} = \frac{P_n}{2K_T K_n \cos\varphi_n \cos 30° C_w} = \frac{P_n}{1{,}73 K_T K_n C_w \cos\varphi_n}.$$

By adjusting the phase shift and current, maximum readings are obtained at the nominal voltage first on one $\alpha_{1\,max}$ and then on the other $\alpha_{3\,max}$ wattmeter. Next, without changing the current setting, readings α_1

and α_3 are obtained on the reference wattmeters by adjusting the phase shifter. If the above operation is carried out correctly and carefully these values are obtained simultaneously.

After the phase shift corresponding to the given power factor $\cos\varphi$ is set, the instruments are checked in the normal way by setting the readings of the instrument under test by means of current adjustment in both series circuits. Let us stress once more that the phase shift is set under conditions of uniform phase loading, whereas any further checking can be carried out with unequal loading. In this instance it is advisable to have the facility of changing the value of the reference wattmeter calibrations (for instance, by connecting current transformers). The adjustment of the reference instrument readings then required is very simple. However, under these conditions care should be taken that the series wattmeter circuits are not overloaded, since this could occur without being noticed at power factors of the order of 0.5.

Checking instruments designed for a four-conductor network by means of three single-phase wattmeters presents no difficulties if the above considerations are taken into account.

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STUDY OF AN INFRASONIC GENERATOR

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Generators of infrasonic frequencies (ISF) are of considerable interest in connection with the application of frequency methods in testing automatic control systems.

The greater part of the commercial automatic systems (for instance in the chemical industry) operate in the range of 0.01 to 1 cps. Study of pneumatic and hydraulic regulators and servosystems also requires sources of harmonic oscillations of 0.01-20 cps.

The ISF generators which are now being used consist mostly of operational amplifier circuits which solve a second order differential equation:

$$\frac{d^2U}{dt^2}+\omega_0^2 U=0.$$

The solution of this equation is a harmonic oscillation of frequency ω_0 [1]. Generators of this type are extremely complex, since they incorporate two integrators with stabilized supplies. The maximum period of oscillations of an ISF generator with double integration is limited by time constants, i.e., by the over-all dimensions of capacitors. The stabilization of the amplitude leads to an increased time in attaining stable oscillations.

The circuit we here propose is to a considerable degree free from these defects.

Below we describe an electromechanical ISF generator, based on a new principle, proposed by F. Rule (GDR), and provide the results of its testing.

Method of obtaining ISF oscillations. The generator [2] employs a moving coil system with an electrical feedback (Fig. 1). The instrument's moving system is not balanced with respect to its axis of rotation. The mechanical moment of its unbalance in a general case is:

$$M_u = gmr \sin \alpha, \qquad (1)$$

where g is the acceleration due to gravity; m is the mass of the moving system; r is the distance between the system's center of gravity and its axis of rotation; α is the angle between the moving system and the vertical axis at a certain instant.

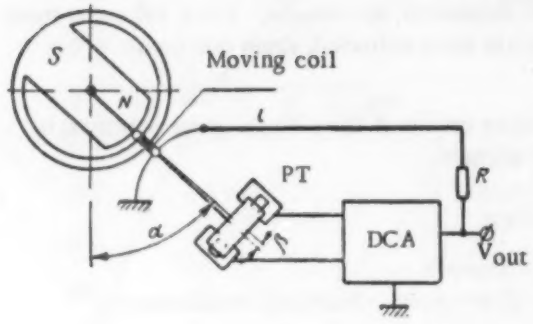

Fig. 1. Principle of operation of an infrasonic generator.

This moment is balanced by moment M_c, produced by the current of the moving coil which is placed in the field of a permanent magnet:

$$M_c = \frac{Bswi}{9810} = k_e i,$$

where B is the induction in the air gap of the magnet, gauss; s is the area of the moving coil, cm^2; w is the number of turns in the coil; i is the current in the moving coil, amp.

The equality $M_u = M_c$ is obtained by means of a servosystem with a dc amplifier DCA in its feedback circuit. As transducers PT of the moving system's position (with respect to the axis of symmetry of the magnetic system SN – Fig. 1) photovaristors are used. When the whole system is rotated (including the photovaristors and the magnetic system) $\alpha = \omega t$, where ω is the system's angular velocity. The mechanical moment is measured according to the sinusoidal law (1).

The servosystem maintains $M_u = M_c = \sim i$ at each instant. Hence:

$$i = I_m \sin \omega t,$$

where $I_m = \frac{gmr}{k_e}$,

and the output voltage is:

$$V = V_m \sin \omega t.$$

Thus this system may be used as a generator of a sinusoidal voltage.

Errors of this method. The most important limitations of this method consist in the errors due to friction, a finite unbalance of the moving system, and the effect of the centrifugal force (at frequencies approaching 1 cps).

Equality $M_u = M_c$ is met providing there are no parasitic mechanical moments of which the most important is the moment of friction.

In an actual system:

$$M_c = M_v + M_f,$$

where M_f is the moment of friction.

Then:

$$i = \frac{M_v}{k_e}\left(1 + \frac{M_f}{M_v}\right).$$

In order to obtain high accuracy it is necessary to construct the instrument's moving system in such a way that ratio M_f/M_u is made as small as possible. The value of the moment of friction is determined by the weight of the moving system and the construction of its bearings. The friction moment is reduced to a minimum if centers are used as bearings. In this instance pivots are used which provide a more accurate location of the moving system with respect to the magnet air gap. The moment of friction is:

$$M_f = fRG,$$

where f is the coefficient of friction; R is the radius of the pivot; G is the weight of the moving system.

The center of gravity of the system must be placed as far as possible from its axis in order to reduce the value of M_f/M_u. Nonlinear distortion can easily be evaluated if the moving system's sagging β, due to the finite gain of the amplifier, is taken into account. The moment of loading in this instance is:

$$M_c = gmr \sin(\alpha - \beta).$$

Since $M_u = M_c$, we have:

$$i = I_m \sin(\alpha - \beta) = I_m [\sin\alpha \cos\beta - \cos\alpha \sin\beta]. \quad (2)$$

On the other hand current i is proportional to angle β:

$$i = k\beta,$$

where k is the gain of an open-circuited feedback.

For the above system $\beta = 0.01$ rad, $I_m = 5 \cdot 10^{-3}$ amp, $k = 0.5$ amp/rad, and it is possible to assume that $\cos\beta \approx 1$, $\sin\beta = \beta = i/k$.

By inserting these values in (2) we have

$$i = I_m \frac{\sin\alpha}{1 + 10^{-2}\cos\alpha}.$$

By expanding i into a series and neglecting all the terms higher than the second, we have:

$$i = 5 \cdot 10^{-3} (\sin\alpha - 5 \cdot 10^{-3} \sin 2\alpha).$$

The current output voltage contains a second harmonic with an amplitude not exceeding $5 \cdot 10^{-3}$ of the reference voltage maximum value, i.e., the coefficient of nonlinear distortion does not exceed 0.5%. Higher harmonics are only produced by the nonlinearity of the amplifier and the photovaristors, but their amplitude is at least one order below that of the second harmonic.

If the axis of symmetry of the moving system does not coincide with the generator's axis of rotation, a dc component appears in the output voltage due to the centrifugal force (Fig. 2). The moment of the centrifugal force is:

$$M_{cf} = F_1 l, \text{ but } \frac{F_1}{F} = \frac{h}{R}, \quad F = m\omega^2 R,$$

$$M_{cf} = hlm\omega^2.$$

Since the moment of the centrifugal force is proportional to the square of the angular velocity, the dc component attains an appreciable value at frequencies above 0.5 cps. The maximum relative error due to the centrifugal force (at 1 cps) must not exceed 0.1%.

$$\frac{M_{cf}}{M} < 0.1\% \approx 10^{-3}.$$

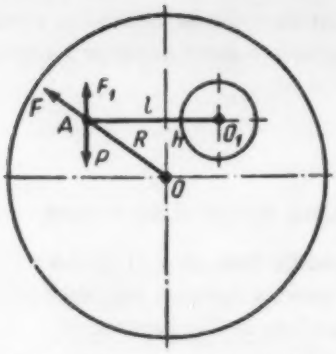

Fig. 2. Effect of the centrifugal force on the operation of the ISF generator. 0) Generator's center of rotation; 0') moving system's center of rotation; A) center of gravity of the moving system; *l*) distance between the moving system's axis and the center of mass; R) distance between the generator axis and the center of mass; h) displacement of the moving system from the generator's axis of symmetry.

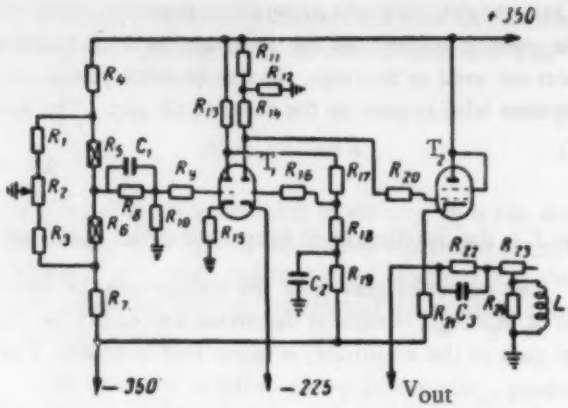

Fig. 3. Schematic of the infrasonic generator.

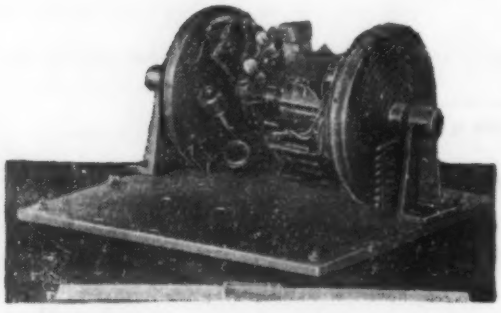

Fig. 4. Infrasonic generator.

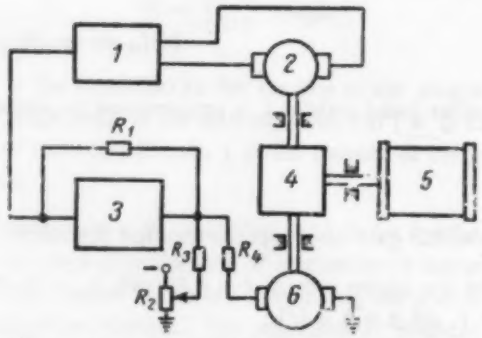

Fig. 5. 1) Power amplifier; 2) motor; 3) DCA; 4) reduction gear; 5) generator; 6) tachometer generator.

The maximum working moment $M = Pl = Mgl$ is:

$$\frac{M_{cf}}{M} = \frac{h\omega^2}{g} < 10^{-3}.$$

Hence h must be made as small as possible:

$$h < 10^{-3}\,\frac{g}{\omega^2} \simeq \frac{10^{-3}\cdot 10^3}{4\pi^2\cdot 0.25} = 0.1\,\text{cm}$$

The basic part of the generator's electronic circuit consists of a device which is affected by small angular deviations of the moving system from its balanced position (along the NS axis – Fig. 1). The device consists of a phototransducer and an amplifier (Fig. 3).

Two photovaristors type FS-K2 serve as phototransducers. Photovaristors of this type possess a high specific sensitivity (2500 μa/ml), a low noise level and can operate at high temperatures (of the order of 80°C). Photovaristors type FS-K2 have a relatively high time constant $\tau = 31 \cdot 10^{-3}$ sec. However, tests have shown that such a value of τ is acceptable. The illuminator lamps are fed from a dc source in order to avoid pulsations at the amplifier input at double the mains frequency. The photovaristors are connected into a resistive bridge circuit (R_1, R_2 and R_3). The shutter which is connected to the moving system is, in zero position of the generator, between the two photovaristors covering half their light-sensitive surfaces. When the generator is rotated the illumination of the photovaristors changes and produces a signal at the input of the amplifier. The three-stage feedback amplifier has a gain of A = 100.

The amplifier feeds the system's moving coil with its building-out resistor. The maximum output voltage of the amplifier is 100 v.

It becomes obvious from the above that if the open-circuited gain of the feedback circuit is raised, the nonlinear distortion factor will decrease. Tests have shown that the upper limit to which the gain can be raised is determined by the stability conditions of the system, which can become self-oscillating at audio frequencies. The stability of the system is greatly improved by introducing into the first stage of the amplifier a differentiating network (R_8, R_{10} and C_1), which reduces the mean rate of decrease in gain with a rising frequency. It is known that this will also decrease the transient process.

The static (residual) error of the servosystem is the smaller, the greater the gain at low frequencies. In order to raise the gain at the lowest frequencies, an integrating network (R_{18}, R_{19} and C_2) was introduced, which does not produce a noticeable phase shift at higher frequencies in the working range.

Capacitance C_3 decreases considerably the effect of external mechanical shocks, vibrations of the reduction gear, etc., on the generator, since it increases the current through the moving coil during transient processes. The output impedance of the circuit R_{22} and C_3 is small at high frequencies, hence, large current variations produce small variations in the output voltage. Moreover, C_3 improves the transfer function of the open-circuited system at higher frequencies and raises its stability.

The shape of the output voltage also depends on the uniformity of the field in the magnet gap. With a nonuniform gap the amplitude of the positive half-period of the output voltage differs from that of the negative half-period. The nonuniformity of the field must not exceed 0.1%.

The generator looks like a rotating drum 130 mm in diameter and 175 mm long (Fig. 4). Two identical systems displaced geometrically by 90° are placed inside the drum. Thus, the generator produces two quantities, one sinusoidal and the other cosinusoidal. The magnet is made of an ANKO-4b alloy. It is 2 cm high. The distance of the gap from the rotation axis is 1 cm.

The moving system is made of bakelized paper and the shutter of aluminum foil 0.1 mm thick. The bearings consist of jewels (rubies) and the pivots were taken from a "Pobeda" watch. The pivot diameter is 0.1 mm.

The rotating mechanism which consists of a motor and a reduction gear is mounted on the same plate as the generator. The motor is of the MS-2T type, with a speed of rotation of n_{min} = 360 rpm and n_{max} = 4800 rpm.

The reduction gear is provided with three gear changes in the range of 0.01 to 1 cps. Within each range the frequency is changed continuously by means of the reference voltage of the servosystem which controls the speed. The servosystem with its d.c. tachometer generator provides a constant speed of rotation and hence a stable generator frequency with an error not exceeding ± 0.2%. The block schematic of the device for controlling speed is shown in Fig. 5. The size of the entire panel does not exceed 260 × 260 mm.

SUMMARY

As the result of the tests carried out by us it was established that the electromechanical infrasonic generator provides two sinusoidal voltages, displaced in phase by 90°. The phase angle error between these voltages does not exceed ± 0.2 the range of the generated frequencies is 0.01-1 cps; the frequency instability does not exceed ± 0.2%; the maximum output voltage is 100 v; the amplitude instability does not exceed ± 0.3%; the nonlinear distortion factor does not exceed ± 0.5 %; and the maximum background noise and interference at the output does not exceed 300 mv in the dynamic operating condition.

The generator completely satisfies the requirements of precision measuring generators in the range of infrasonic frequencies.

G. A. Martynov and Yu. I. Yanova participated in this development work.

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HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

MODEL EQUIPMENT FOR MEASURING SMALL POWERS IN THE DECIMETER RANGE

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January, 1961

The D. I. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM) has developed a model equipment for measuring small powers which consists of power meters of two types, namely, calorimetric and bolometric meters, and a device for their comparison.

The calorimetric power meter (Fig. 1) is based on the absorption of the measured power in the calorimetric attachment (Fig. 2), which consists of a short-circuited section of a coaxial line with losses. A central conductor of the calorimetric load carries a tubular carbon-covered resistor, which is cooled from the inside by running water. The power dissipated in this resistor produces an increment in the water temperature, whose value is measured by means of a differential thermopile. The measurement is made by the method of substituting the ultrahigh frequency power by a low frequency power.

The water is pumped through the calorimetric attachment by means of a centrifugal pump. In order to stabilize the water temperature a temperature equalizing unit consisting of two tinned copper coaxial cylinders is used. The helical pipe formed between them serves to conduct the water to the calorimetric attachment.

The calorimetric power meter has a power level of 100-500 mw; a frequency range of 0-1700 Mc; an input impedance of 75 ohms; a voltage standing wave ratio in the range of 150-1700 Mc not exceeding 1.1; and a quadratic mean error in a series of measurements of 0.2%.

The calorimetric power meter in conjunction with the comparator device makes it possible to certify and check the mean power under continuous oscillating conditions of all the existing small-power meters in the range of 30 to 1000 Mc with powers from 50 μw to 500 μmw.

Moreover, the small effect of frequency on the calorimeter readings makes it suitable for studying wattmeters and ammeters at audio and ultrasonic frequencies.

The bolometric power meter consists of a bolometric head with an airtight wire bolometer which absorbs the measured power [1], and a bolometric bridge [2].

In order to ensure sufficiently small reflections over a wide frequency range the bolometric heads carry two bolometers which are connected in series for the direct current and in parallel for the UHF power.

This bolometric power meter has the following characteristics: frequency range of 30-1000 Mc; input impedance of 75 ohm; voltage standing wave ratio in the above frequency range not exceeding 1.07; power range from 10 to 10000μw; efficiency of the head of 99% (correction factor not exceeding 1.01); the error in power measurements due to the bridge circuit does not exceed $\pm (0.1 + 42/P)\%$, where P is the measured power in μw; the error of the bolometric power meter does not exceed $\pm (0.6 + 42/P)\%$, where P is the measured power in μw.

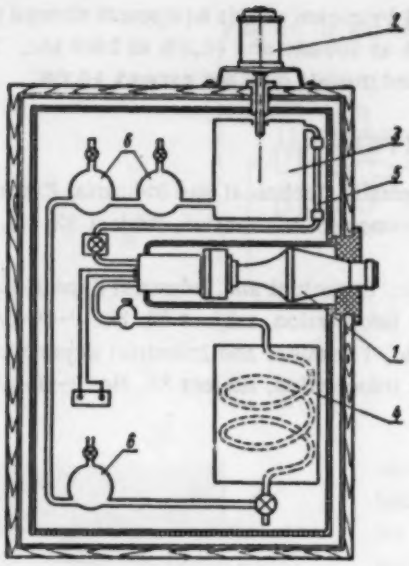

Fig. 1. 1) Calorimetric attachment; 2) motor; 3) pump; 4) temperature-equalizing unit; 5) ratemeter; 6) trap.

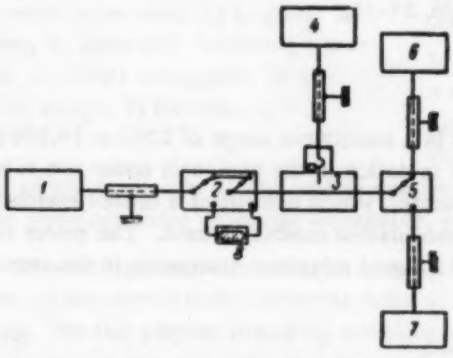

Fig. 3. 1) UHF generator; 2) coaxial switch; 3) directional coupler, type IPSK-2; 4) test receiver type IP-2; 5) coaxial switch; 6) reference calorimetric power meter; 7) thermistor or bolometric power meter under test; 8) attenuator type FAD-5/20.

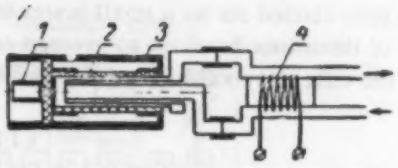

Fig. 2. 1) Jack; 2) resistance load; 3) frame; 4) thermopile.

The principle of operation of the comparator (see Fig. 3) consists in the following: the power from the UHF generator is fed to the reference and the tested power meters, which are in turn connected to the output of the main branch of the directional coupler. At the same time the ratio of the transmitted powers is measured by means of voltage ratio meter (test receiver type IP-2 of the "Étalon" plant [3]), which is connected to the side branch of the directional coupler.

The error of the tested power meter is determined from:

$$\delta = \frac{P_t}{P_s} A - 1,$$

where P_t and P_s are the powers of the tested and reference power meters respectively; A is the ratio of the powers transmitted to the reference and the tested instruments.

For measuring the transmitted power (the difference between the incident and reflected power) a directional coupler is used with a common directional element for the incident and reflected wave, thus almost completely eliminating the error due to mismatch.

When a thermistor or bolometric head is certified, the latter together with the additional bridge is connected to the comparing device as a power meter under test. The efficiency of the head is determined from the formula:

$$\eta = \frac{P_t}{P_s} A.$$

The comparator provides the possibility of comparing two power meters with their ranges differing by 30-40 db at frequencies from 30 to 1000 Mc and a minimum measured power of 50 μw; and a certifying thermistor and bolometric heads and a comprehensive checking of power meters at the level of 50 μw – 500 mw against a reference bolometric or calorimetric power meter.

The quadratic mean error due to the reference equipment when comparing two power meters does not exceed ±0.5%, providing the voltage standing wave ratio of the instruments being compared does not exceed 2.

The maximum possible error due to the reference equipment when certifying heads does not exceed ± 0.5% (when measurements are repeated ten times).

The systematic error of checking does not exceed 0.2%.

Any reflections encountered in practice from the power meters and heads under test do not add any systematic errors to the measurements.

The tests carried out on a small power meter type IMM-6 by means of this equipment showed that the efficiency of thermistor heads on an average are equal to 99.6% at 200 Mc and 96.3% at 1000 Mc. The dispersion of the efficiency values from the mean of the three tested models does not exceed ±0.6%.

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REFERENCE EQUIPMENT FOR CALIBRATING NOISE GENERATORS IN THE UHF RANGE

L. A. Birger, B. N. Shvetsov, and I. A. Sokov

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 37-40, January, 1961

A special reference equipment for testing noise generators in a continuous range of 1000 to 10,000 Mc has been developed. The spectral density (temperature) of noise radiation of the generator under test is measured by comparing it with the radiation of a reference noise generator, which consists of a heated matched load (the black body method) [1, 2]. For picking out weak signals a modulation method is used. The power ratio of the calibrated and reference generators is measured by means of a cutoff reference attenuator in the intermediate frequency channel of a superheterodyne amplifier.

By means of calibration the relative temperature is obtained:

$$\theta_{ng} = \frac{T_{ng} - T_0}{T_0} \tag{1}$$

or

$$A_{ng} = 10 \log \theta_{ng} \text{ (db)}. \tag{2}$$

where T_{ng} is the effective radiation temperature of the noise generator under calibration; $T_0 = 293°K$ is the normal temperature.

The quantity θ_{ng} (or A_{ng}) we shall call relative temperature of "additional" noise. It is precisely this characteristic that is of interest in the practical use of noise generators.

Let us specify that we take quantity T_{ng} to be the temperature corresponding to the maximum spectral density of noise power which the given generator can supply into a matched load (i.e., into a load whose impedance is the conjugate of the generator's output impedance).

The equipment consists of a measuring rack and five plug-in high-frequency channels. Four channels consist of waveguides with cross sections of 72 × 34, 48 × 24, 35 × 15, and 23 × 10 mm, which cover a frequency range of 2600 to 10,000 Mc. The fifth channel consists of a coaxial line with a characteristic impedance of 50 ohm and covers the range of 1000 to 2600 Mc.

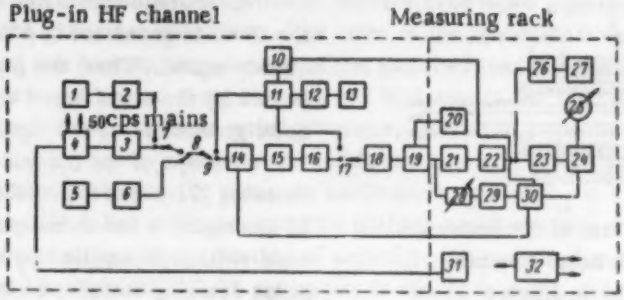

Fig. 1.

The block schematic of the equipment is shown in Fig. 1.

A "cold" (at room temperature) matched load 5, reference noise generator 3 ("black body") and noise generator 1 under calibration are connected in turn to the input of high-frequency modulator 14 (mechanical or ferrite) by means of waveguide switches 7, 8 and 9.

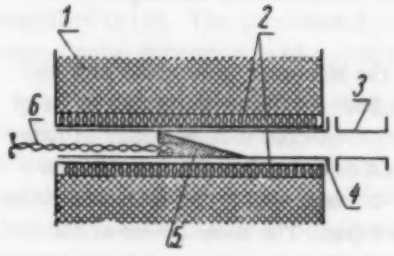

Fig. 2. Simplified schematic of the construction of a waveguide reference noise generator. 1) Lagging; 2) heaters; 3) thermally insulating waveguide; 4) nickel waveguide; 5) absorbing wedge; 6) thermocouple.

The reference noise generator consists of a muffle oven inside which the matched load is placed (Fig. 2, 3). In the range of 2600-10,000 Mc the load consists of a waveguide section with an absorbing wedge made of green carborundum (Fig. 2), and in the range of 1000-2600 Mc the load consists of a coaxial line section whose central conductor is covered over a certain distance by a metal oxide layer which serves as an absorbing resistance (Fig. 3). By means of a special circuit consisting of temperature control unit 4 (Fig. 1) and automatic potentiometer 31 the difference of temperatures between the "black body" and the cold matched load is stabilized. The transducer of the automatic potentiometer consists of a thermocouple whose hot junction is placed in the middle part of the reference noise generator waveguide, and its cold junction on the body of the cold matched load.

In order to avoid errors due to mismatching, the cold load and the generator under calibration are matched before measurements to the reference noise generator so as to have equal moduli and phases in their reflection factors. For this purpose matching transformers 2 and 6 are used.

The matching is checked by means of a bridge circuit consisting of a high-frequency bridge 11 (a waveguide double T-junction or a directional coupler), a matched load 13, and a matching transformer 12. The bridge is fed from signal generator 10. A superheterodyne receiver on the test rack serves as an indicator for the bridge and is connected to the bridge circuit by means of a waveguide switch 17.

The high-frequency modulator (mechanical or ferrite) is synchronized by means of an electron modulator 30, and overlaps the channel for about half the period thus modulating the signal being compared. The modulation frequency amounts to approximately 33 cps. In the above circuit the compared signals are fed to the indicating part of the circuit through the same high-frequency modulator channel. Hence no strict requirements are necessary with respect to the shape and duration of the pulse thus produced. Only its stability is important.

The modulated signal is fed through a high-frequency amplifier 16, which works with a traveling-wave tube (TWT), and through an image-channel filter 18 to mixer 19 fed from oscillator 20 and then to the intermediate frequency amplifier (IFA) 21. A ferrite rectifier 15 is connected between the modulator and the amplifier in order to eliminate parastic noise modulation in the TWT (in the range of 1000-2600 Mc rectifiers are not used).

The input of the IF amplifier is also supplied with a reference signal from the intermediate frequency noise generator 29 (IFNG) through reference attenuator 28. The intermediate frequency is 60 Mc with a bandwidth of the order of 6 Mc. The IF noise generator provides a signal with a mean frequency of 60 Mc and a bandwidth of 1-2 Mc.

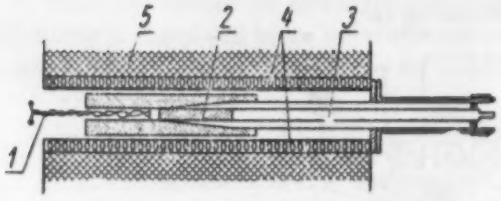

Fig. 3. Simplified schematic of the construction of a coaxial reference noise generator. 1) Thermocouple; 2) absorbing resistance; 3) coaxial line; 4) heaters; 5) lagging.

Electronic modulator 30 manipulates the signal of the IF noise generator in phase opposition to the high-frequency signal. Thus, the input of the IF amplifier is fed in turn by the transformed signal of the high-frequency noise generator and the signal of the IF noise generator. The envelope of the modulated signals is reproduced by detector 22. From the modulation frequency amplifier 23 the signal is fed to the phase detector 24, whose reference voltage is supplied by the electronic modulator. The phase detector includes an integrating network with a time constant of 1 or 3 sec. Indicator 25 is connected to the output of the phase detector. For visual observation of the modulated signals an oscilloscope indicator 27 with a video-amplifier 26 are connected to the output of the IF detector. The device is fed from a 400 cps stabilized source 32.

The measuring process consists of the following. First the cold load, the reference noise generator and the noise generator under calibration are matched by means of transformers both for the modulus and phase of their reflection factor. The matching is measured on a high-frequency bridge. A cold matched load at room temperature T_x (in general it differs from the normal temperature T_0) is then connected to the input of the circuit. The phase detector is adjusted for zero with the IF noise generator disconnected. The reference noise generator with an effective noise temperature of T_e is then connected to the input. The noise power at the input of the amplifier is then increased by a value proportional to $T_e - T_x$. The IF noise generator is switched in, the reference attenuator set to 0 db (the attenuator is calibrated in such a way that 0 db corresponds to maximum attenuation), and the IF noise generator signal is adjusted to be equal to that of the reference generator by bringing the phase detector indicator to zero.

The noise generator under test is next connected to the circuit and the signals are again equalized by means of the reference attenuator (without changing the setting of the IF noise generator). The obtained attenuator reading A, which is then noted, is related to temperatures T_{ng}, T_e and T_x by the expression

$$A = 10 \log \frac{T_{ng} - T_x}{T_e - T_x} \text{ (db)}. \tag{3}$$

Let us denote

$$A_e = 10 \log \frac{T_e - T_x}{T_0}. \tag{4}$$

This quantity, which is recorded in the reference generator certificate, is constant since the difference of temperatures $T_e - T_x$ is stabilized by means of a special circuit.

In the above equipment A_e = 3.00 db ($T_e - T_x$ = 585°K) in the range of 2600-10,000 Mc, and A_e = 1.50 db ($T_e - T_x$ = 414°K) in the range of 1000-2600 Mc.

From (1)-(4) we find by means of simple transformations that the required relative temperature of the noise generator radiation is:

$$A_{ng} = A + A_e + 4{,}34 \frac{T_x - T_0}{T_{ng} - T_0}. \tag{5}$$

The last term in (5) is a correction which accounts for the deviation of the room temperature from normal. Normally this correction is small and can be neglected. For instance, for a gas discharge tube $T_{ng} - T_0 \approx$ ≈ 19,000°K. If the room temperature deviates from normal by ± 15°K the error will not exceed ± 0.004 db.

The correction becomes appreciable for the calibration of low-temperature generators. For instance, under the same conditions for $T_{ng} - T_0$ = 600°K the correction attains ± 0.11 db.

Errors. The calibration error amounts to the error of the reference noise generator and that of comparing the reference generator with the generator under test. The error of the reference noise generator is determined by the inaccuracy in measuring the heating temperature of the matched load, instability of temperature, the uneven heating of different parts of the load along its axis, and by losses in the thermally insulating waveguide, which is connected to the output of the reference noise generator. Owing to a special control system the temperature instability and the error in its determination lie within the limits of ± 5°K for a heating temperature of the order of 600°K, which corresponds to a noise generator calibration error of $\Delta_T = \pm 0.04$ db. In developing the reference generators, steps were taken to ensure a highly uniform heating temperature distribution along the operating (radiating) part of the matched load. Testing of experimental samples has shown that irregularities in the temperature distribution did not exceed 3°K for generators in the 3 cm range and 6°K for generators in the 10 centimeter range. The losses in the thermally insulating waveguide are essentially a function of the operating frequency and attain a maximum in the 3 centimeter range where they amount to 0.05-0.1 db. Errors due to the uneven heating of the matched load and losses in the waveguide can be partly eliminated by the method described in [3]. The uncorrected part of that error is evaluated to be 0.03-0.07 db. The total error Δ_e of reference noise generators is of a systematic nature and does not exceed 0.08 db.

The error made in comparing the generator under test with the reference generator is due to inaccuracies in the reference attenuator, difference in the losses of the tested and reference generator channels, internal noise effects, and the instability of the IF noise generator and other elements of the circuit. The error due to the unequal losses in the tested and reference generator channels may amount to 0.3-0.5 db. However, in certifying the equipment this error is considerably reduced by applying appropriate corrections. In order to determine these corrections two gas discharge noise generators are compared, one of which replaces the reference generator and the other the generator under test. Comparison is made twice, with the position of the generators interchanged. The residual part of this error is determined by the accuracy in comparing two noise generators and does not exceed ± 0.10 db.

Let us note that in calibrating noise generators by means of the "black body" method a considerable error may be caused by reflections [4, 5]. In order to eliminate this error the equipment includes a high-frequency bridge. An important part is also played by the use of a traveling-wave tube and of ferrite rectifiers. The traveling wave tube reduces the sensitivity threshold to fluctuations and the ferrite rectifiers sharply decrease the effect of the high-frequency channel impedance, which is connected to the amplifier, on the amplifier internal noises.

The total error in comparing the reference generator with the generator under test is characterized by the following quantities: the random error (the quadratic mean deviation of various measurements) $\sigma = \pm 0.10$ db, and the residual part of the systematic error $\Delta_{se} = \pm 0.14$ db.

The total error of calibrating the noise generator is determined from the formula:

$$\Delta = \sqrt{\frac{(3\sigma)^2}{n} + \Delta_{se}^2 + \Delta_e^2} \qquad (6)$$

where n is the number of measurements. Thus, for n = 5 the error of calibration $\Delta = \pm 0.2$ db.

Repeated calibrations of noise generators made by means of the reference equipment confirm the accuracy in determining these errors. For instance, the quadratic mean deviation of a series of measurements of five measurements each, obtained during more than 300 calibrations of noise generators by means of gas discharge lamps GSh-1 and GSh-2 did not exceed 0.10 db in 95% of the cases. Most often a quadratic mean deviation in the range of 0.04-0.06 db was observed. In certain instances abnormally large quadratic mean deviations of 0.15-0.18 db were obtained in a series of measurements. Special investigations have proved that they were caused by the instability of the radiating temperature of certain gas discharge lamps.

Repeated calibrations of several gas-discharge noise generators have shown that the differences in the calibration results (arithmetic mean of a number of measurements) do not exceed 0.10 db. These results indicate both the accuracy of the reference equipment and the relatively high stability of the gas-discharge noise-generators.

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AUTOMATIC WAVEGUIDE MEASURING LINE

A. S. Elizarov

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Automatic measuring lines (AML) raise considerably labor productivity when measuring voltage standing wave ratios (VSWR). However, a wide application of these lines is prevented by their low accuracy (± 10% in some lines), which is due to the presence of moving elements (a probe or a rotating disc phase shifter).

The proposed version of an automatic measuring line provides a purely electrical displacement of the field pattern with respect to the probe. It is based on fairly simple principles.

If in the VSWR measuring circuit described in [1] the dielectric phase shifter is replaced by a ferrite one and its coil is fed with a saw-tooth current, a displacement of the field pattern with respect to a stationary probe will be provided. If in addition the vertical plates of the oscilloscope (operating in a driven condition) are supplied with an amplified probe signal, the oscilloscope screen will show the distribution pattern of the field and it will be possible to determine the VSWR by means of a special scale. The block schematic of the proposed automatic line is shown in Fig. 1.

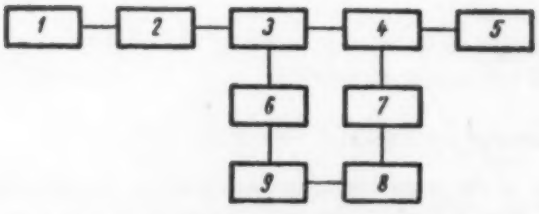

Fig. 1. 1) Amplitude modulated HF oscillator; 2) matching transformer; 3) probe head; 4) ferrite phase shifter; 5) waveguide element subject to adjustment or checking; 6) vertical amplifier; 7) saw-tooth generator; 8) synchronizing pulse generator; 9) oscilloscope.

All the elements of this circuit with the exception of the ferrite phase shifter are well known and, therefore, we shall only deal with the requirements which that shifter has to meet.

The ferrite phase shifter must provide a maximum sum of phase shifts for two electromagnetic waves propagated in opposite directions, hence, it must be reversible. It is desirable that it should provide large phase shifts per unit length of ferrite for a minimum power of the saw-tooth generator.

Reversible phase shifters which meet the above requirement have been investigated experimentally [2] and their electrodynamic computation is provided in [3].

Errors in automatic lines when measuring VSWRs. 1. The random error due to the indication system for a maximum image level of 50 mm on the oscilloscope screen when measuring a VSWR = 3 does not exceed ± 5%. Therefore we can assume that:

$$\delta_1 = \pm 5\%$$

2. The systematic error due to the deviation of the detector characteristic from a square law in the majority of cases does not exceed ± 1%. Let us assume:

$$\delta_2 = \pm 2\%.$$

3. The systematic error in the mistuning of the generator is due, when working with a phase shifter, to a phase shift in the reflected wave at the generator owing to a change in the electrical length of the channel. From the results obtained in [4] this error can be expressed by the formula:

$$\delta_{3\,max} \simeq \pm 2\,|\Gamma_g| \cdot |\Gamma_1| \cdot 100\%,$$

Where $|\Gamma_g|$ is the modulus of the generator reflection factor, and Γ_1 is the modulus of the load reflection factor.

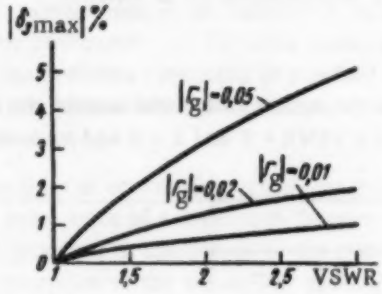

Fig. 2.

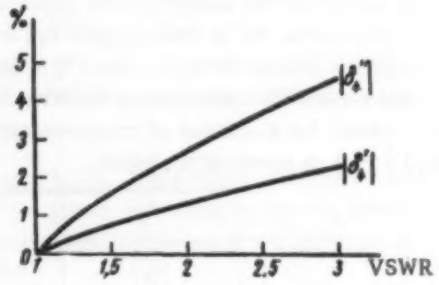

Fig. 3.

The relation between $\delta_{3\,max}$ and the VSWR is shown in Fig. 2, from which it will be seen that it is necessary to match the generator for at least a VSWR = 1.05. The matching can be accomplished very quickly by means of the line itself. For this purpose it is only necessary, for instance, to interchange the positions of the phase shifter and the probe head, whose output should be closed with an end cap. This method of matching is rather inconvenient since the equipment has to be dismantled. This, however, can be avoided if the method of measuring the generator VSWR described in [6] is used.

4. Systematic error due to losses in the phase shifter. According to experimental data [2] the losses in an improved phase shifter do not exceed 0.8 db in the absence of a magnetic field, and are no more than ± 0.2 db in the presence of a magnetic field. Moreover, the phase shifter remains reversible with respect to losses as well (owing to the placing of the ferrite along the waveguide axis and the small external magnetic field strength).

The systematic error due to the first source may be accounted for by method [1], if the modulus $|Q|$ of the phase shifter transfer constant is measured in advance. This, however, does not eliminate the random error due to inaccurate measurements of $|Q|$, an error which is evaluated from the formula

$$\delta_4' = \pm \frac{4\,|Q|\,|\Gamma_1|\,\Delta|Q|}{1-|Q|^4\,|\Gamma_1|^2} 100\%. \qquad (1)$$

where $\Delta|Q| = \pm 0.0105$ for an accuracy of loss measurements of ± 0.1 db. The systematic error δ_4'' due to the second source can also be evaluated from (1) but in this instance $\Delta|Q| = \pm 0.021$. The relation of δ_4' and δ_4'' to the VSWR is shown in Fig. 3.

5. The systematic error due to reflections from the phase shifter (owing to the presence of $|\Gamma_p|$) is evaluated in the most unfavorable case according to [1] from the formula:

$$\delta_{5\,max} = \pm \frac{1{,}41\,|\Gamma_p|}{1-|\Gamma_1|^2} 100\%.$$

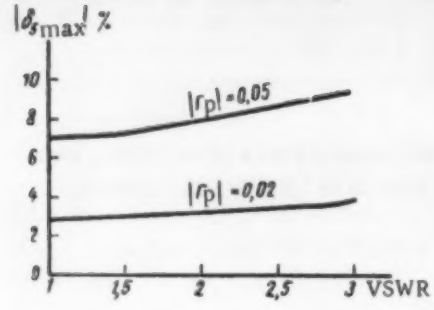

Fig. 4.

Figure 4 shows the relation $\delta_{s\max}$ and VSWR for various values $|\Gamma_p|$.

6. The systematic error due to the shunting effect of the probe. Since the distance between the probe and the generator is strictly constant, the shunting of the probe affects, according to [7], the measurement accuracy of the VSWR only owing to $|\Gamma_1| > 0$ and involves an error ~ 3% for a VSWR = 3 and a $|\Gamma_2| = 0{,}03$ (modulus of the probe reflection coefficient). Owing to the constant coupling factor between the probe and the waveguide, the insertion of the former can be reduced to a minimum determined by the power of the generator and the sensitivity of the detector. This makes it possible in many instances (especially when small VSWRs are being measured) to neglect this error altogether. Nevertheless let us assume:

$$\delta_6 = \pm 2\%.$$

The total error of an automatic measuring line, determined as the square root of the sum of the squares of all the above errors, for a number of measurements k, calculated for a VSWR = 3 and k = 3 and various values of $|\Gamma_g|$ and $|\Gamma_p|$ is given in the table.

$\lvert\Gamma_g\rvert$	0,02		0,01	
$\lvert\Gamma_p\rvert$	0,05	0,02	0,05	0,02
VSWR	±11,6	±7,8	±11,5	±7,6

SUMMARY

The suggested version of an automatic measuring line is as accurate in measuring voltage standing wave ratios as any of the known automatic lines, but it has an advantage in its simplicity of construction.

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PULSE TESTING OF RADIO INTERFERENCE METERS

L. A. Pereverzev

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 42-46,
January, 1961

A radio interference meter,* which in essence consists of a measuring receiver is first of all tested as a normal receiver, i.e., with a sinusoidal voltage. However, this testing is insufficient, since it does not indicate the dispersion of readings between instruments which arises in measuring actual non-sinusoidal interference. A particularly large dispersion should be expected in the case of pulse interference, hence, testing with a sinusoidal voltage should be supplemented by testing with a pulsed voltage. The necessity for such testing is now generally recognized, since it provides a better opportunity of checking the properties of the instruments than the separate measurement of the detector band width and time constant, which remain useful for the purpose of adjusting the instrument. At the same time, however, opinions differ with respect to the technique of pulse testing and the characteristics required of a pulsed voltage. A discussion of these questions seems, therefore, advisable, especially in view of the fact that it is contemplated to formulate a GOST (State All-Union standard) for interference meters.

Readings of an interference meter fed with a periodic pulse train. Interference meters are tested with a periodic pulse train of a repetition frequency starting from single pulses and rising to the top limit at which the transient processes at the output of the interference meter tuned amplifier have not yet had time to decay before the reception of the subsequent pulses.

When a pulse is received by the interference meter a response will be produced at the output of its amplifier:

$$u(t)=\frac{1}{\pi}\int_0^\infty S(\omega)\,k(\omega)\cos[\omega t+\psi(\omega)+\varphi(\omega)]\,d\omega,$$

where S (ω) and ψ (ω) are the modulus and phase of the pulse spectral density; k(ω) and φ (ω) are the modulus and phase of the amplifier transfer constant.

A correctly designed interference meter is a selective device. Its band width is made sufficiently narrow so that the pulse spectral density remains almost unchanged within that band. Hence:

$$u(t)=2S(\omega_0)\frac{1}{2\pi}\int_{\omega_1}^{\omega_2}k(\omega)\cos[\omega t+\varphi(\omega)]\,d\omega \quad \text{or} \quad u(t)=2S(\omega_0)\,g(t). \tag{1}$$

where S (ω_0) is the modulus of the spectral density in the pass band; g(t) is the time (pulse) characteristic of the amplifier; ω_1 and ω_2 are the boundaries of the pass band beyong which k(ω) becomes negligibly small.
ligibly small.

Thus, at the output of the amplifier there is a response whose shape is determined exclusively by the properties of the amplifier, and whose amplitude is proportional to the spectral density of the input signal at the tuned frequency.** This response is fed to a quasi-peak detector. The direct voltage $U_=$ (providing the

* Henceforth we shall call a radio interference meter for the sake of brevity IM.

** The latter fact is sometimes lost sight of. Thus, in [1] an expression is given for the response amplitude at the output of an interference meter tuned amplifier

$$V_0 = kE\Delta f,$$

where E is the pulse amplitude (short) at the input of the interference meter; Δf is the bandwidth; k is the coefficient related to the amplifier channel parameters.

This relationship is incorrect, since for the same amplitude of a short pulse its spectral density may differ (it is determined by the area of the pulse).

repetition frequency is not too low) at the output of the detector is proportional to the maximum value of the response u_{max}, with the coefficient of proportionality (coefficient of detection) r being a function of the repetition frequency F_r:

$$U_{-} = r(F_r)\, u_{max}$$

Considering that:

$$u_{max} = 2S(\omega_0)\, g_{max}$$

and that the time characteristic may be represented as:

$$g(t) = k(\omega_0)\, g_н(t),$$

where

$$g_н = \frac{1}{2\pi} \int_{\omega_1}^{\omega_2} \frac{k(\omega)}{k(\omega_0)} \cos[\omega t + \varphi(\omega)]\, d\omega;$$

and $k(\omega_0)$ is the gain at the mean frequency, we obtain:

$$U_{-} = r(F_r)\, k(\omega_0)\, g_{н\,max}\, 2S(\omega_0).$$

When the instrument is calibrated by means of a sinusoidal voltage the same voltage is obtained at the output of the detector (for the same deflection of the measuring instrument pointer) according to the equation:

$$U_{-} = k(\omega_0)\, r_{sin}\, U.$$

where U is the effective value of the sinusoidal voltage; r_{sin} is the detection coefficient for a sinusoidal voltage.

From the equality of the left-hand sides it follows:

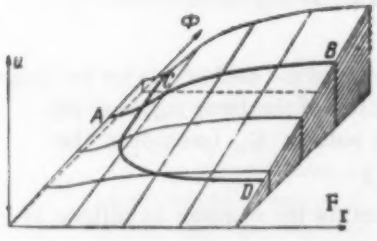
$$U = \frac{r(F_r)}{r_{sin}}\, g_{\ max}\, \Phi(f_0),$$

where $\Phi(f_0) = 2S(\omega_0)$

In case of linear detection $r(F_r)\, g_{н\,max} / r_{sin} = K(F_r)$ only depends on the repetition frequency, and does not depend on the level of the signal. The reading of an interference meter:

$$U = K(F_r)\, \Phi(f_0) \qquad (2)$$

may be represented graphically for a fixed tuned frequency of f_0 as a two-dimensional relationship (see figure). It is obvious that for a fixed frequency an interference meter may be considered as measuring spectral density.



Relation of an interference meter's readings to the spectral density and repetition frequency of pulses.

For extremely low repetition frequencies the above reasoning applies with the unessential difference that the comparison of the effects produced by pulses and a sinusoidal voltage must then be made by observing the deflections of the instrument pointer, and not by measuring the detector output voltage, since the pulsations which would then appear at its output make it necessary to take into consideration the inertia of the indicating instrument.

Technique of pulse testing. In fact, the object of pulse testing is determining coefficient $K(F_r)$, which is best of all measured as such. The accepted separation of the coefficient into a constant numerical factor and a so-called equivalent band-width [2] appears to us to be an artificial device, which can only lead to a distortion of the principle of testing and would result in obtaining a time instead of a frequency characteristic.

The absolute value of $K(F_r)$ should be determined in at least one reference point (with respect to the repetition frequency) of the surface (see figure) as a ratio of the instrument reading to the spectral density of the pulses fed to its input:

$$K(F_{cr_0}) = \frac{U}{\Phi(f_0)}.$$

For the remaining points it is sufficient to determine the ratio of the coefficients at those points and that at the reference points. This can be done in various ways.

For a constant pulse spectral density it is possible to check the following ratio:

$$\frac{U}{U_0} = \frac{K(F_{cr})}{K(F_{cr_0})},$$

which corresponds to curve AB and in a certain scale provides the graph for $K(F_r)$. Such a characteristic is given, for instance, in one of the draft specifications of the International Committee on Radio Interference (CISPR) for an interference meter [3].

The second method consists of determining for the constant reading of U the relation:

$$\frac{\Phi(f_0)}{\Phi_0(f_0)} = \frac{K(F_{r_0})}{K(F_r)};$$

This ratio corresponds to curve CD, which represents a graph for relationship $1/K(F_r)$, which is cited in a later version of the CISPR specification [4].

The advantage of the first method consists in obtaining a sinusoidal voltage at a variable level by means of the existing apparatus. The requirement of changing the output level of the spectral density sources may complicate their construction. The second method is better from the point of view of indicating the possible overloading of the interference meter. However, it is also possible to determine overloading by the first method, providing the gain is changed while a certain reading α of the indicating instrument is kept constant. Since external calibration is normally used, it is possible to work at any gain, thus avoiding overloading.

Relationship $K(F_r)$ has a monotonic character which differs little from instrument to instrument, and therefore the number of check points with respect to the repetition frequency need not be large. If checking is not extended to very low frequencies, it is sufficient to measure in one or two additional points.

Pulse generator requirements. It follows from (2) that the pulse voltage used for testing must have a definite absolute spectral density at the tuned frequency. Moreover, the required repetition frequency range must be covered.

For a sufficient selectivity of interference meters (absence of any noticeable spurious response), the requirement for a uniform spectrum must only be met, as it will be seen from (1), in the pass band of the instrument. Since an interference meter is a narrow-band instrument, this requirement is satisfied by pulses of almost any shape.

It should be noted that for certain tests (for instance when testing interference meters for cross modulation, which can be considered as one of the selectivity tests) short pulses are used with a uniform spectrum over the whole frequency range of the instrument; the use of pulses of another shape for these tests would change substantially the results obtained. However, obtaining a uniform spectrum for such experiments, which may be necessary for testing instruments, is made easier by the fact that in this instance it is sufficient to know the absolute spectral density only very approximately.

In checking coefficient $K(F_{r0})$, however, it is necessary to reproduce the spectral density with a greater accuracy than that of the checked parameter. Even if we consider the tolerance for $K(F_{r0})$ of ± 1.5 db given in the CISPR draft [4] to be generous, the tolerance for reproducing $\Phi(f_0)$ will still have to be of the order of 1 db. Attaining such an accuracy is not an easy task. Therefore, the requirement for a sufficiently accurate

reproduction of the spectral density must be the determining factor in choosing the shape of test pulses, at least for initial measurements.

Determination of the spectral density. In computations of the spectral density based on the use of a Fourier integral various definitions may be used, since the existence of a coefficient in determining spectral density, i.e., in a direct Fourier transformation, is accounted for by a corresponding notation in the inverse transformation.

However, in measuring spectral density we in fact stopped at the first stage of this operation, and therefore from the point of view of making the results comparable to each other it is desirable to use a single definition of spectral density.

Normally in specifying the response of interference meters to a pulsed voltage the problem of spectral density is avoided, and the latter is fixed indirectly in the form of pulse [5] or generator [4] parameters, which makes the comparison of interference meter specifications difficult.

It seems expedient to determine spectral density for measurement purposes in the following manner.

The pulse spectral density is expressed in a complex form:

$$S(j\omega)=\int_{-\infty}^{+\infty} f(t)\,e^{-j\omega t}\,dt. \qquad (3)$$

Let us pass in the inverse transformation:

$$f(t)=\frac{1}{2\pi}\int_{-\infty}^{+\infty} S(j\omega)\,e^{j\omega t}\,d\omega$$

from a complex form to a real one; let us take into account that for a real function of f (t) we have $S(-j\omega) = S^*(j\omega)$ or:

$$S(j\omega)=S(\omega)\,e^{j\psi(\omega)} \text{ and } S(-j\omega)=S(\omega)\,e^{-j\psi(\omega)}.$$

Moreover, by changing angular frequency ω for frequency f we have:

$$f(t)=\int_{0}^{\infty} 2F(f)\cos[2\pi ft+\chi(f)]\,df,$$

where $F(f) = S(\omega)$ and $\chi(f) = \psi(\omega)$.

In this case the spectral density is:

$$\Phi(f)=2F(f)=2|S(j\omega)|.$$

The last expression together with (3) is suitable for specifying spectral density in measurements, since it is expressed in terms of real values of amplitude and frequency f at which measurements are made. On the other hand, this expression is convenient for computations, since they are made by using the complex form of (3).

As an example of the application of this definition let us give a few expressions of spectral density for certain common forms of pulsed voltages.

For a pulse with a sharply rising front ("jump")

$$\Phi=\frac{A}{\pi f},$$

where A is the pulse amplitude.

For a short pulse

$$\Phi = 2q,$$

where q is the pulse area.

In a particular case of a rectangular pulse:

$$\Phi = 2A\tau,$$

where τ is the pulse duration.

In a case of a pulse obtained in a circuit with a discharging capacitance (a so-called exponential pulse):

$$\Phi = 2ERC,$$

where E is the voltage of the source; C is the discharging capacitance; R is the load resistance.

As an example of misunderstandings which arise due to insufficient attention being paid to the determination of spectral density we can quote the following relation given in [6]:

$$U_1 = kF(\omega)\,\Delta f = kERC\Delta f,$$

where U_1 is the amplitude of the oscillatory pulse at the output of the intermediate frequency amplifier; k is the amplification factor; Δf is the band width.

It would be more correct to write, assuming the intermediate frequency filter is ideal, that:

$$U_1 = k2ERC\Delta f.$$

Direct measurements of spectral density. In testing interference meters the absolute value of spectral density is usually obtained by indirect measurements, namely, from parameters of a pulse as a function of time. In certifying pulse generators, however, it is desirable to check this computation, which lies at the basis of such measurements, by means of a direct measurement of the spectral density.

It is often assumed that it is possible to measure the absolute value of spectral density by means of a filter (amplifier) with a rectangular pass band characteristic without a previous calibration against a source with a known spectral density. The essence of the reasonings in support of such a method may be reduced approximately to the following. Since the pass band approaches a rectangular characteristic, it is possible to assume in (1) that $k(\omega) = k = \text{const}$ within the pass band and $k(\omega) = 0$ outside this band. It is also assumed, this time without sufficiently valid reasons, that the phase characteristic is linear, i.e., $\varphi(\omega) = -\omega t_1$. Then:

$$u(t) = 2Sk\int_{f_1}^{f_2} \cos 2\pi f (t - t_1)\, df$$

or

$$u(t) = \Phi k\Delta f \cdot \frac{\sin \pi\Delta f (t - t_1)}{\pi\Delta f (t - t_1)} \cos 2\pi f_0 (t - t_1),$$

where

$$\Delta f = f_2 - f_1;$$

$$f_0 = \frac{1}{2}(f_1 + f_2);$$

$$\Phi = 2S.$$

The maximum value is:

$$U_{max} \quad \Phi k \Delta f,$$

whence

$$\Phi = \frac{U_{max}}{k} \cdot \frac{1}{\Delta f},$$

or after referring the voltage to the input

$$\Phi = \frac{U_{max}}{\Delta f},$$

where $U_{1\,max} = U_{max}/k$.

However (4) cannot serve as a basis for an accurate measurement of spectral density, since in its derivation the correct equation for the phase characteristic was ignored. In [7] it is shown that for an increased number of sections n of a band pass filter its frequency characteristic tends to an ideal rectangular shape, but its phase characteristic tends to deviate increasingly from a straight line. A solution which is obtained in the assumption of a linear phase characteristic cannot, therefore, be claimed to have a close approximation to the transient processes in an actual band-pass filter circuit. Thus, for a five-section band pass filter, with a frequency characteristic very close to a rectangular shape, the maximum instantaneous response differs from that for an ideal filter by 17%.

In many instances a sufficiently reliable and accurate method of measuring the spectral density of a single pulse consists in measuring the harmonics of a discrete spectrum of repeated pulses of the same shape. It is known [8] that the value of spectral density $S(j\omega)$ of a single pulse at points $\omega = k\,\Omega_r$ coincides with the value C_k/F_r, where C_k is the coefficient for the k-th complex harmonic of a Fourier series for repeated pulses; $\Omega_r = 2\pi F_r$.

Assuming that for these points:

$$[S(j\omega)]_{\omega = k\Omega_r} = \frac{C_k}{F_r}$$

and taking into consideration that the actual amplitude of the harmonic is $U_k = 2|C_k|$, we obtain:

$$\Phi_{f=kF_r} = \frac{U_k}{F_r}.$$

Thus, the determination of the spectral density is reduced to measuring two quantities, which makes this method more advantageous as compared to measuring the response of a tuned amplifier, whose frequency characteristics it is necessary to know in order to determine from it the pulse characteristic.

Pulse generators intended for checking interference meters must have a maximum repetition frequency not less than a few kilocycles. For such values of F_r the method of measuring by means of harmonics can be easily attained. By feeding the signal to a receiver which has a sufficiently narrow band (a band width smaller than F_r), picks out the k-th harmonic and suppresses all the others, it is possible to measure the value of U_k. Since the repetition frequency can be varied with an error negligibly small as compared to the error in measuring U_k, the value of Φ may be determined, in a favorable case, with an error not greater than that involved in measuring a sinusoidal voltage.

The frequency range in which such measurements are possible (for video pulses) is limited by the fact that at high frequencies (starting at 10-20 Mc) the accuracy is decreased, mainly owing to the instability of the pulse repetition frequency. However, even in the case when measurements are only possible at the lower end of the spectrum, their results are extremely useful, since subsequent variations of the spectral density with frequency can be determined by means of relative measurements.

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TECHNIQUE AND APPARATUS FOR DETERMINING THE TRANSIT ERROR IN DIODE VOLTMETERS

A. M. Fedorov

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 47-48, January, 1961

The transit error of diode voltmeters may be determined from Megaw's formula [1] whose accuracy, however, is low. As far as we know there is as yet no satisfactory theory for determining the transit error. In view of the need for determining the transit error we have developed a method for its experimental determination which is described below.

The transit error of diode voltmeters at voltages of 0.1 to 1 v may be computed from their frequency error, which can be determined by means of thermistor voltage meters from formula:

$$\theta_{\sigma t} = \left(\frac{1 + \frac{\theta_{\sigma f}}{100}}{1 + \frac{\theta_{\sigma r}}{100}} - 1 \right) \cdot 100\%, \qquad (1)$$

where $\Theta_{\sigma t}$ is the voltmeter transit error; $\Theta_{\sigma f}$ is the total voltmeter frequency error determined experimentally; $\Theta_{\sigma r}$ is the voltmeter resonance error [4].

At voltages higher than 1 v this technique cannot be applied owing to the limited amplitude range of thermistor meters.

For determining the transit error at voltages exceeding 1 v we have developed a technique based on measuring the voltage ratio by means of a superheterodyne receiver type IP-2 [5]. A block schematic for measuring the transit error of voltmeter type OKV-2 is shown in Fig. 1. The test receiver has at its input a diode mixer, and a reference attenuator in the intermediate frequency stage. The receiver amplitude characteristic is linear over a wide range of frequencies (up to 1000 Mc) and amplitudes (up to 60 db). The receiver frequency range is covered up to 1000 Mc by means of the first, second, and third harmonics of the heterodyne oscillator.

The technique in determining the transit error amounts to the following. The voltage corresponding to the voltmeter reading V_{V1}, whose transit error has been determined from (1), is fed from the generator through

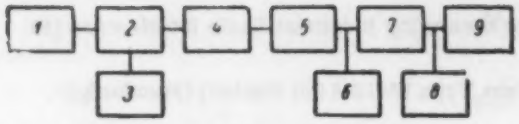

Fig. 1. 1) Generator type GSS-12; 2) coaxial switch type SVCh-6; 3) load type UÉA-5; 4) resonance filter type FR-2; 5) impedance transformer type TIM; 6) voltmeter type OKV-2; 7) cutoff attenuator type APP; 8) test receiver type IP-2; 9) coaxial load.

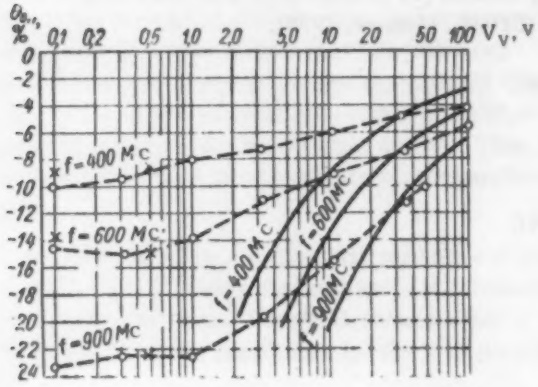

Fig. 2.

the filter and impedance transformer to the input of the voltmeter under test. Such voltage can have the value, for instance, of 1 v. It is advantageous to make this a reference value, since at voltages of the order of 1 v the thermistor voltage meter has minimum random errors. The voltage fed to the voltmeter is simultaneously applied through a cutoff attenuator (40-60 db) to the input of the test receiver, and the reading of its output instrument is noted. An additional attenuation is then introduced by means of the reference attenuator in the receiver circuit, and the measured voltage is raised to restore the reading of the receiver output instrument to its previous value. Another reading V_{v2} of the voltmeter is then taken. Thus, the actual voltage ratio at the voltmeter input is measured by means of the receiver and the ratio of the voltmeter readings noted. By comparing the ratios of the voltmeter and the test receiver readings it is possible to determine the relative variation of the voltmeter transit error, since there will be no resonance error providing the frequency of the voltage remains constant and its shape sinusoidal. In such a case the required value of the transit error may be computed from the formula:

$$\theta_{0t2} = \left[\left(1 + \frac{\theta_{0t1}}{100}\right)\frac{\alpha}{\beta} - 1\right] \cdot 100\%, \qquad (2)$$

where θ_{0t2} is the value of the transit error to be determined and corresponding to the voltmeter reading V_{v2}; θ_{0t1} is the known value of the transit error which corresponds to voltmeter reading V_{v1}; α is the actual value of the voltage ratio at the voltmeter input determined by the variation in the receiver attenuator reading; $\beta = V_{v1}/V_{v2}$ is the ratio of the voltmeter readings.

It should be remembered that the presence of harmonic components in the measured voltage may lead to a considerable error due to the inequality of resonance errors in the first and second instance [6]. For suppressing harmonics we used in the circuit of Fig. 1 a filter type FR-2, whose figure of merit in the range of 200 to 1000 Mc was not less than 200.

The largest possible error in measuring the transit error by this method with the above apparatus at a voltage of 100 v and ten repeated readings does not exceed ±0.4% for frequencies up to 400 Mc, ±0.6% for frequencies up to 600 Mc, and ±0.7% for frequencies up to 1000 Mc.

In Fig. 2 the dotted lines represent the experimentally obtained relation of the transit error to the measured voltage at 400, 600 and 900 Mc for a reference compensation-type OKV-2 voltmeter with a 2D1C diode, which had a distance of 125 μ between its electrodes in a hot state. The crosses on the graph represent the values of the transit error computed from (1) on the basis of the experimental data obtained by comparing the voltmeter with a thermistor voltage meter. These values are in satisfactory agreement with those obtained by means of the equipment here described. The full lines shown on the same graph represent the transit error values computed from Megaw's formula [1].

It will be seen from the above relationships that the transit error values computed from Megaw's formula do not agree with experimental data. This was to be expected, since the formula was derived by neglecting the initial speed of electrons.

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MEASUREMENT OF A GENERATOR OUTPUT ADMITTANCE BY MEANS OF A MEASURING LINE

A. I. El'kind and N. A. Zemskaya

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In the UHF range it is often necessary to measure the voltage standing wave ratio of the generator section. For this purpose several methods have been developed [1, 2, 3]. However, in a number of cases it is necessary to measure the output impedance or admittance of a generator section which consists of a generator and decoupling attenuator. Thus, if the impedance is known, it becomes possible to choose matching elements and their position in the line when matching generator sections, to evaluate with the consideration of phase relations the effects of mismatching between the generator and loading parts of the line, etc.

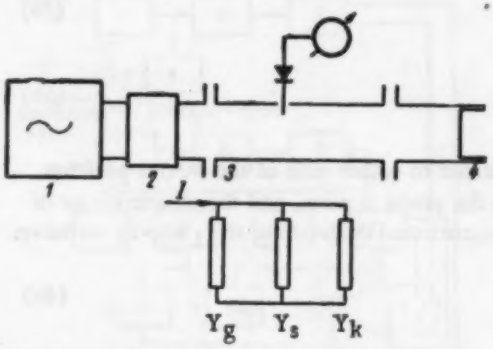

Fig. 1. 1) Generator; 2) decoupling attenuator; 3) measuring line; 4) short-circuiting device.

The above method may be called that of a moving short-circuiting device and a stationary probe. The relation between a stationary probe of a measuring line (Fig. 1) and the position of a shorting device makes it possible to determine the output admittance of the generator section with respect to the probe cross section.

In this measurement the standing wave node and the probe are first placed at the cross section where the output admittance is being determined. The initial position of the shorting device is noted on its scale. The shorting device is then adjusted to find two positions, one to the right and the other to the left of the initial position, in which the voltage across the probe is equal to a quarter of its maximum value. For a square law detector the measurement amounts to finding the two positions corresponding to half the scale reading. In other cases detector calibration curves should be used. The two positions thus found are noted on the scale of the shorting device. The two distances from the measured to the initial position determine the two components of the output admittance. The computing formulas have the form:

$$\mathrm{re}\,Y = \frac{\cot \beta l_1 + \cot \beta l_2}{2}, \tag{1a}$$

$$\mathrm{im}\,Y = \frac{\cot \beta l_2 - \cot \beta l_1}{2}, \tag{1b}$$

where reY and imY are the real and imaginary components of the admittance referred to the characteristic admittance of the line; l_1 is the absolute distance from the initial position to the position obtained in displacing the shorting device away from the probe; l_2 is the absolute distance obtained in the same displacement towards the probe: $\beta = 2\pi/\lambda_g$ is the phase constant; λ_g is the wavelength in the line.

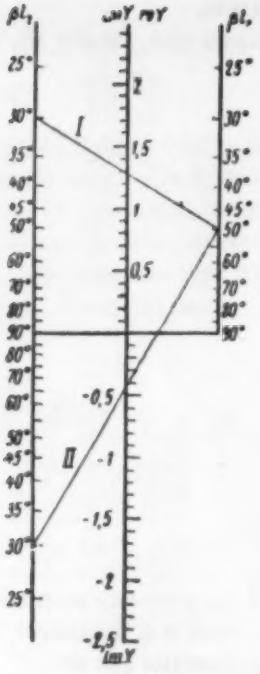

Fig. 2.

Formulas (1a) and (1b) are convenient for plotting simple nomographs (Fig. 2) in which the output admittance components are plotted linearly along their axis, but the phase distances βl_1 and βl_2 are plotted along their axes according to a cotangent law. In order to find the components of the output admittance a rule should be placed to intersect the points corresponding to the measured values of the phase distances βl_1 and βl_2. The position of rule I, which is shown in Fig. 2 indicates the real component, and that of rule II the imaginary component (along the lower axis of βl_2).

To prove the formulas (1a) and (1b) let us examine the equivalent circuit of a current generator at the cross section in which the probe is placed (Fig. 1). At the above cross section there are three admittances: the output admittance of the generator section Y_g to the left, the shunting admittance of the probe Y_k, and the effective admittance of the shorting device $Y_s = -j\cot\beta x$ to the right, where x is the distance between the plane of the short circuiting device and the above cross section. The square of the voltage amplitude, which is proportional to the indicator reading in a square law detector, can be written in the form:

$$|V|^2 = \frac{I^2}{[\mathrm{re}(Y_g + Y_s)]^2 + [\mathrm{im}(Y_g + Y_s) - \cot\beta x]^2}. \tag{2}$$

It is obvious that the maximum squared amplitude corresponds to a value of x, for which the second term in the denominator (2) becomes zero. Half the maximum squared amplitude corresponds to a value of x for which the second term is equal to the first. Hence the condition of half the maximum squared amplitude can be written in the form:

$$\mathrm{re}(Y_g + Y_s) = \mathrm{im}(Y_g + Y_s) - \cot\beta x_1, \tag{3a}$$

$$\mathrm{re}(Y_g + Y_s) = -\mathrm{im}(Y_g + Y_s) + \cot\beta x_2. \tag{3b}$$

Relationships (3) are solved for βx_1 and βx_2 lying respectively in positions to either side of the initial position $\beta x_0 = n\pi$ of the shorting device for either of which the voltage across the probe is zero, and the denominator of the right-hand side of (2) becomes infinite. According to the above-mentioned definitions of l_1 and l_2 we have:

$$\beta x_1 = n\pi - \beta l_1, \tag{4a}$$

$$\beta x_2 = n\pi + \beta l_2. \tag{4b}$$

From (3a) and (3b) we find:

$$\mathrm{re}(Y_g + Y_s) = \frac{\cot\beta l_1 + \cot\beta l_2}{2},$$

$$\mathrm{im}(Y_g + Y_s) = \frac{\cot\beta l_2 - \cot\beta l_1}{2}.$$

By neglecting Y_s as compared with Y_g we obtain (1a) and (1b).

It follows from the above that in fact it is the sum of the generator section output admittance and the shunting probe admittance that is measured. Hence the absolute error in measuring the generator section output admittance due to the presence of the probe is numerically equal to its shunting admittance. The nominal admittance of probes in standard measuring lines normally amounts to 0.01-0.02. Another error may arise due to the line coupler between the probe and the shorting device. This error cannot be eliminated. If the S-curve of the coupler [3] is plotted, it is advisable to determine the position of the shorting device plane, when measuring impedance or admittance, by the scale of the line using the S-curve as a graph for converting the line scale readings to those of the shorting device scale.

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OSCILLOSCOPE FOR MILLIMICROSECOND PULSES

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In recent years various devices have come into use which employ pulses with a rise time of 1-10 mμsec, thus making it necessary to develop high-speed oscilloscopes.

Below we give a brief description of a high-speed oscilloscope which makes it possible to investigate the shape and measure the parameters of millimicrosecond pulses.

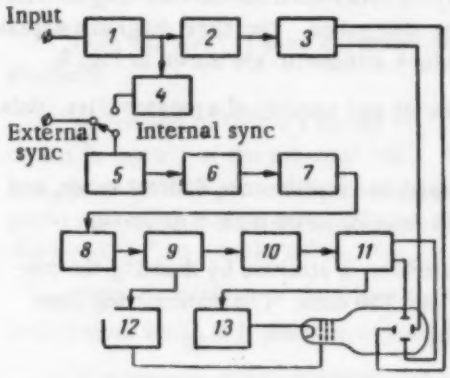

Fig. 1. 1) Preamplifier; 2) delay line; 3) amplifier; 4) cathode follower; 5) phase inverter; 6) pulse amplifier; 7) frequency divider; 8) cathode follower; 9) blocking oscillator; 10) artificial delay line; 11) scanning units; 12) timer; 13) brightness unit.

The oscilloscope is characterized by high speed scanning (0.004-0.1 μsec/cm), a wideband amplifier with a 95 Mc band width and a gain of the order of 57 db constructed on the principle of distributed amplification.

The oscillograph (see block schematic in Fig. 1) consists of three circuits, the operating, sweep and calibrating circuits.

The operating circuit comprises a vertical amplifier (VA) and a delay line (DL).

The signal under test is fed to the vertical amplifier and the delay line which delays the appearance of the signal on the screen of the cathode-ray tube (CRT) with respect to the beginning of the sweep.

From the vertical amplifier the signal is fed to the vertically deflecting plates of the CRT.

The scanning circuit comprises a synchronizer, an artificial delay line (ADL), a sweep generator and a brightness generator.

Since it was required to design an oscilloscope whose scanning could be tripped by pulses of at least 500 kc repetion frequency and the maximum frequency of the sweep generator did not exceed 50 kc, great attention was paid to developing the synchronizing unit. The main part of this unit consists of a four-stage frequency divider with trigger elements, which divides the frequency in steps by a factor of two up to a factor of 16, which makes it possible to trip the scanning by pulses with an 800-1000 kc repetition frequency. In order to raise the sensitivity of the synchronizer the frequency divider is preceded by a pulse amplifier which provides the tripping of the scanning unit by pulses with amplitudes of the order of 0.15 v. The phase inverter at the input of the synchronizer makes it possible to start the scanning unit by means of pulses of either polarity.

The sweep generator consists of stages for converting starting signals into rectangular pulses and a circuit for shaping the saw-tooth voltage.

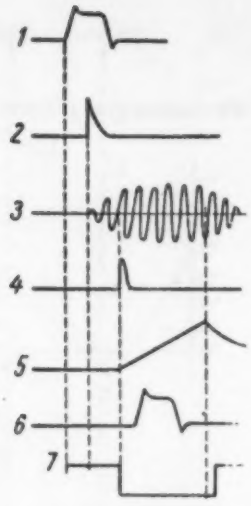

Fig. 2. 1) Signal under test; 2) signal at the output of the frequency divider; 3) voltage at the output of the timer; 4) starting signal at the output of the artificial delay line; 5) sweep voltage; 6) pulse under test at the output of the delay line; 7) brightness pulse.

The method of getting rectangular voltage shapes by means of a system of voltage limiters and amplifiers, widely used in the technique of forming milli- and microsecond pulses, cannot be applied in this instance owing to stray capacitances which shunt the limiters and increase the rise time of output signals. Far better results are obtained in the technique of generating millimicrosecond pulses by using circuits consisting of several driven blocking oscillators. In this circuit each succeeding blocking oscillator is tripped by the preceding one, thus providing rectangular pulses with steeper edges than those of the tripping pulses. The advantage of this system over limiters and amplifiers consists in the fact that in the blocking oscillators, owing to their positive feedback, the rate of the pulse rise considerably exceeds the rate of the voltage rise on the grid of an amplifier-limiter.

The output of the blocking oscillator circuit is connected to an amplifier-limiter for the purpose of improving the shape of the pulse tops. The input of the sweep generator is connected to an artificial delay line by means of which it is possible to delay the starting of the sweep from 0 to 190 mμsec, thus displacing horizontally the pulse observed on the CRT screen. This provides the possibility of viewing in a large scale separate parts of the pulses under investigation. The duration of the processes under observation is calibrated by feeding a second pair of vertically-deflecting plates of the CRT by a high frequency sinusoidal voltage, obtained from generators which are synchronized with the sweep voltage. Thus, amplitude time markers appear on the oscilloscope screen with a repetition period of 3, 10 and 50 mμsec.

The error of the pulse time parameters does not exceed 10%.

The calibrator is tripped by a signal received from the blocking oscillator, which in turn is started by the scanning unit pulses. The time diagrams explaining the operation of the oscilloscope block schematic are shown in Fig. 2.

The vertical amplifier is based on a distributed amplification circuit and consists of a preamplifier, delay line, phase inverter and push-pull penultimate and ultimate stages.

The preamplifier, phase inverter and penultimate stages of the vertical amplifier use 6Zh20P tubes, and the output stage uses 6P14P tubes. The input attenuator is calibrated in steps of 10 db from 0 to 50 db.

Two input impedances of 50 and 75 ohm are provided. Their switching is attained by shunting the preamplifier grid circuit of an impedance of 150 ohm by resistance of 75 and 150 ohm. The transmitting lines of all the vertical amplifier stages consist of low pass m-derived filters.

The maximum output voltage for an input signal of 0.15 v amounts to 100 v.

Externally the oscilloscope has the appearance of a movable two-unit assembly and is used as a laboratory instrument.

V. K. Eliseev and E. L. Karganov participated in this work.

MEASUREMENT OF THE DISPERSION AND ABSORPTION OF ELECTROMAGNETIC WAVES IN POLAR LIQUIDS

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January, 1961

Measurements of the complex permittivity of substances with respect to the frequency of the electrical field for various temperatures provides the possibility of judging the structure and radius of molecules, the value of the dipole moment, relaxation time, and dielectric losses. These measurements are also required for determining the laws of propagation of electromagnetic waves in various media, as well as for developing an improved theory of polarization of substances in direct and alternating fields.

For measuring the dispersion and absorption of decimeter and centimeter electromagnetic waves in polar liquids we have chosen in this work homologous series of normal alcohols: methyl, ethyl, n-propyl, n-butyl, n-amyl, hexyl, heptyl, octyl, nonyl, as well as isoamyl alcohols and diethyl formamide $HCON(C_2H_5)_2$. Measurements were made at wavelengths of 96, 27.2 and 3.18 cm at a constant temperature of 20 ± 1°C.

The subjects for investigation and wavelength ranges were selected so that the fullest results could be obtained in most of the polar liquids under investigation in the range of decimeter and centimeter wavelengths.

Moreover, the dispersion and absorption in such liquids as amyl, hexyl, heptyl, octyl and nonyl alcohols as well as in diethyl formamide have hardly been investigated to date.

The electrical properties of methyl and ethyl alcohols were studied over a wide frequency range in order to check Debye's theory of polarization of liquids in high-frequency fields.

Esau and Baz [1] have experimentally attained a maximum absorption coefficient for methyl and ethyl alcohols.

According to Debye's theory an "impulse wave" λ_s is constant for every polar liquid and does not depend on the frequency of the external field. However, the experimental data obtained by a number of authors show that the value of λ_s for methyl and ethyl alcohols, calculated from measurement results in the range of decimeter and centimeter waves, does not agree with experimentally obtained maxima in curves representing the relation of ϵ'' to wavelengths.

From an analysis of the experimental data obtained for the dielectric properties of normal alcohols of the homologous series it is possible to consider that ϵ'' has one maximum at a given wavelength for each alcohol.

The process of polarizing liquids whose molecules have a complex structure and a shape distinct from a spherical one, varies somewhat with the frequency of the electrical field oscillation. In this connection the values of λ_s, calculated for ϵ' and ϵ'', which were measured at different frequencies, also differ from each other. In Debye's theory this is not accounted for since it assumes a definite model for a molecule, whose polarization process does not vary with frequency.

The values of ϵ', ϵ'' and λ_s in the region of decimeter and centimeter waves for all the homologous series of normal alcohols is of interest for determining the behavior of highly polar substances in rapidly changing electrical fields, and for developing a more precise theory of polarization of substances.

Experimental equipment and measuring methods. For investigating the dispersion and absorption of electromagnetic waves of the decimeter range in polar substances the method of placing a capacitor in a two-conductor line was adopted [2], and measurements made for λ = 27.2 cm and λ = 96 cm. Measurements at wavelength λ = 3.18 cm were made by the waveguide method.

In selecting these methods we aimed at obtaining sufficiently precise results and measuring with small quantities of the substances under investigation, since for solving the above problem highly pure liquids are required.

TABLE 1

Real and Imaginary Components of Permittivity

Substance	λ=96 cm		λ=27,2 cm		λ=3,18 cm	
	ε'	ε''	ε'	ε''	ε'	ε''
CH_3OH	33,2	6,27	27	14	10,0	7,77
C_2H_5OH	23,9	10,4	12,4	—	4,34	2,48
C_3H_7OH	16,3	8,8	6,0	5,42	3,91	1,65
C_4H_9OH	12,4	9,8	4,0	3,65	3,26	1,12
$C_5H_{11}OH$	9,75	5,57	2,7	3,71	3,0	0,58
$C_6H_{13}OH$	7,0	4,69	2,7	2,1	2,84	0,56
$C_7H_{15}OH$	7,63	5,63	2,67	2,0	2,68	0,43
$C_8H_{17}OH$	5,28	4,89	2,32	0,94	2,57	0,34
$C_9H_{19}OH$	6,1	4,6	2,9	2,09	2,39	0,36
$Iso\text{-}C_5H_{11}OH$	—	—	2,4	4,6	2,89	0,61
Diethyl formamide	27,4	5,16	—	—	9,7	9,0

TABLE 2

Maximum Absorption Wavelengths

Alcohols	λ_m, cm	
	λ = 27,2 cm	λ = 96 cm
Methyl	3,2	2,8
Ethyl	8,2	7,3
n-Propyl	16,0	18,7
n-Butyl	23,5	24,4

The study of this method showed that in order to obtain reliable results in measuring conducting liquids in the decimeter range it is necessary to select capacitors of a small value in order to avoid the possibility of negative bias to make allowances in computations for suspensions or equivalent parameters, for the effect of conductivity in the dielectric, and for the attenuation in the measuring line, and to reduce as far as possible the effect of the generator power instability by selecting an optimum coupling between the generator and the measuring lines.

The experimental equipment for measuring in the decimeter range consisted of measuring lines, generators and indicators. Platinum electrode capacitors were made and two of them selected for these measurements. The capacitor constants were determined by filling them with air ($\epsilon = 1$) and benzene ($\epsilon = 2{,}281$).

The accuracy in determining the capacitor constants and the lack of effect in the position of the capacitor in the line on the determination of ϵ' was checked by measuring the ϵ' of water. The mean value of ϵ' for water (capacitor No. 1) for $\lambda = 27{,}2$ cm was found to be 79,2.

For capacitor No. 2 and $\lambda = 96$ cm the mean value of ϵ' for water was 80,4.

An analysis of the measurement errors at wavelengths of 96 and 27,2 cm showed that the maximum error in determining ϵ' and ϵ'' was about 5%.

Measurements in the range of centimeter wavelengths were made with measuring lines of the three-centimeter range by means of two versions of the shorted waveguide method [3], thus making the results comparable to each other.

1. The probe was adjusted to be at a maximum electric field for a zero thickness of the dielectric (the plunger was placed tightly against the mica diaphragm), and to remain there stationary throughout the measurements. The plunger was lifted smoothly by rotating the micrometer screw, thus between the bottom of the plunger and the diaphragm a space was obtained which was filled with the liquid fed from the upper part of the

measuring section through grooves cut in the narrow sides of the plunger. Thus, plane-parallel layers of the liquid under investigation were obtained, whose thickness could easily be determined with an error not exceeding 0.01 mm. Simultaneously with the movement of the plunger a curve was plotted of the relation between the indicator readings and the thickness of the liquid dielectric. The movement of the plunger in these measurements was equal to 25 mm. Resonance curves were plotted both when the liquid layer thickness was increased and decreased. A complete coincidence of these curves was observed, providing the klystron generator's operation remained constant. The distance between two minima of the curve was taken to be half the wavelength in the dielectric ($\frac{1}{2}\lambda_d$).

The computation of ϵ' and ϵ'' was made from the formulas:

$$\varepsilon' = \left(\frac{\lambda}{\lambda_c}\right)^2 + \frac{\lambda^2}{4\pi^2}(\gamma_2'^2 - \gamma_2''^2); \tag{1}$$

$$\varepsilon'' = \frac{\lambda^2}{4\pi^2} 2\gamma_2' \gamma_2'', \tag{2}$$

where λ_c is the critical wavelength in the waveguide; λ is the wavelength in free space; γ_2' and γ_2'' are the real and imaginary components of the electromagnetic wave propagation constant in the dielectric.

The values of γ_2' and γ_2'' were determined from the relations:

$$\gamma_2' = \frac{2\pi}{\lambda_d}; \tag{3}$$

$$\text{th}\gamma_2'' d_n = \sqrt{\frac{\sqrt{P\min}}{\sqrt{P_0} - \sqrt{P_n\min}} \cdot \frac{\sqrt{P_0} - \sqrt{P_0\max}}{\sqrt{P_n\max}}} \quad (n = 1, 2, 3\ldots) \tag{4}$$

where P_0, $P_{n\max}$ and $P_{n\min}$ are the readings of the square-law detector for a zero thickness of the dielectric, and for thicknesses multiples of $\lambda_d/4$; $d_n = n\lambda_d/2$.

2. Knowing the wavelength λ_d in the dielectric, the plunger was placed at a distance $\underline{d}$ from the diaphragm ($\underline{d}$ was made a multiple of $\lambda_d/4$). In displacing the probe curve was plotted of the electrical field distribution along the waveguide. The measuring section was then filled with liquid and while the probe was being moved another curve of the field distribution in the waveguide was plotted. From these measurements the value of x_0, the distance of the first standing wave node from the dielectric layer, and the voltage standing wave ratio ρ were determined. The computation of ϵ' was made from the formula:

$$\frac{\text{th}\gamma d}{\gamma d} = \frac{i\lambda_g}{2\pi d} \cdot \frac{\frac{1}{\rho} - i\tan\frac{2\pi x_0}{\lambda_g}}{1 - i\frac{1}{\rho}\tan\frac{2\pi x_0}{\lambda_g}}, \tag{5}$$

where λ_g is the wavelength in the waveguide.

The stability of the generator frequency was checked by means of a heterodyne frequency meter of the three-centimeter range. The variation in frequency during one hour did not exceed 0.19 Mc, which amounts to 0.002%.

An analysis of the systematic and random errors in measuring ϵ' and ϵ'' by the waveguide method showed that the maximum relative error of measurement of ϵ' and ϵ'' does not exceed 4%, and that the error rises with a decreasing absorption of electromagnetic waves in the liquids. This points to the limitations in the application of (1) and (2) for computing ϵ' and ϵ'' in liquids with small absorption. The losses in the waveguide walls were not allowed for, since the tested liquids had an absorption considerably exceeding that of the waveguide.

TABLE 3

Relaxation time $\tau \cdot 10^{-10}$, sec			Radius of the molecule $a \cdot 10^{-8}$ cm
alcohols	λ = 27.2 cm	λ = 96 cm	
Methyl	0.08	0.07	1.55
Ethyl	0.17	0.15	1.62
n-Propyl	0.46	0.54	1.91
n-Butyl	0.73	0.76	2.1
n-Amyl	1.37	1.01	2.2
n-Hexyl	1.53	1.46	2.2
n-Octyl	2.54	2.05	–
Isoamyl	2.08	–	–

TABLE 4

Substance	ε_0	n^2	$\lambda_s^{\varepsilon''}$, cm		
			λ=96cm	λ=27,2 cm	λ=3,18cm
CH_3OH	33,7	1,766	17,1	14,0	5,34
C_2H_5OH	25,7	1,852	27,3	30,46	9,31
C_3H_7OH	22,8	1,918	64,5	55,16	9,76
C_4H_9OH	19,2	1,957	76,8	74	11,13
$C_5H_{11}OH$	16	1,987	86,0	117	11,45
$C_6H_{13}OH$	13,7	2,070	106	111,5	11,95
$C_7H_{15}OH$	–	2,025	–	–	–
$C_8H_{17}OH$	9,8	2,038	113	140	11,7
$C_9H_{19}OH$	–	2,055	–	–	–
Iso-$C_5H_{11}OH$	5,7	1,981	–	76	–

Measurement results. The above measurements made it possible to calculate the values of ε' and ε'' for homologous series of normal alcohols. The measurement results are given in Table 1.

The experimental data thus obtained for wavelengths of λ = 96 cm and λ = 27.2 cm for methyl, ethyl, n-propyl and n-butyl alcohols show that the "impulse wave" λ_s for these alcohols lies in the region of 12 to 80 cm.

The calculated values of the wavelength λ_m for the maximum absorption coefficient, the relaxation time τ and the radius of molecules for various alcohols are given in Tables 2 and 3.

The calculated results for the "impulse wave" $\lambda_s^{\varepsilon'}$ are given in Table 4.

For the normal amyl, hexyl, heptyl, octyl and nonyl alcohols the calculated values of λ_s cannot be considered satisfactory. This reveals the deficiency of Debye's theory.

Measurement results for λ = 3.18 cm give a particularly sharp deviation from Debye's theory. It will be seen from Table 4 that the calculated values of $\lambda_s^{\varepsilon'}$ for wavelength λ = 3.18 cm are, with the exception of methyl alcohol, are close to each other. Such a result appears to us possible if molecules or parts of molecules close to each other in volume and viscosity are orientated in a high-frequency electromagnetic field. Since the molecules of the tested alcohols are not equal in volume and the liquids possess different viscosities, it can be assumed that parts of molecules of the OH group with a dipole moment, of equal volume, and coupled to an approximately equal degree with the remainder of the molecule, are being orientated in the centimeter wavelength field. These experiments for the first time revealed a region of anomalous dispersion in diethyl formamide.

The conductivity of the tested alcohols and diethyl formamide increases with a rising frequency of the external field (Table 5).

Measurements for λ = 96 cm showed that in methyl, ethyl, n-propyl, and n-butyl alcohols the conductivity rises with an increased number of carbon atoms in an alcohol molecule. It will be seen from the above

TABLE 5

Alcohols	$\sigma \cdot 10^4 \cdot ohm^{-1} \cdot cm^{-1}$		
	λ = 96 cm	λ = 27.2 cm	λ = 3.18 cm
Methyl	11	86	400
Ethyl	18	112	130
n-Propyl	15	33	86
n-Butyl	17	22	58
n-Amyl	9.7	22.7	31
n-Hexyl	8.1	13	29
n-Heptyl	9.8	13	23
n-Octyl	8.5	5.7	18
Nonyl	8.0	12.8	19
Diethyl formamide	9.0	–	460

measurements that such a regular relationship only holds for waves which are above the value of the "impulse wave" for the liquids in question. For a $\lambda < \lambda_s$ the conductivity of alcohols decreases with a rising number of carbon atoms in the molecule. These measurements confirm the conclusion that the conductivity of polar liquids does not attain a maximum for a certain frequency.

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DETERMINATION OF THE ACTIVITY OF A RADIATION SOURCE IN A DENSIMETER WITH IONIZATION CHAMBERS

M. L. Gol'din

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 54-57, January, 1961

Instruments making use of gamma radiators are widely used in industry. Their accuracy depends on the activity of the radiation source.

For measuring pulp the speed of operation is not important [1], hence in instruments intended for this purpose ionization chambers are used for detection. The instrument's measuring circuit, consisting of two ionization chambers connected differentially and an ac amplifier, provides sufficiently accurate and highly stable measurements.

Since the value of gamma radiations is small as compared with the ionization chamber, the beam of gamma rays in this type of instrument is diverging, and it becomes necessary to make allowances for the propagation of gamma-rays in a wide beam. The ratio of the full intensity of radiation to the intensity of primary radiation, calculated according to the law of attenuation for a narrow gamma-ray beam, is known as the increment factor; this factor can be calculated by means of Fano's theory [2].

Moreover, the value of gamma-radiations can be decreased by a rational construction of the chamber and its materials [3], and a correctly selected radioactive element for the given task [4].

A. K. Val'ter, N. G. Afanas'ev and the author of this article have developed a practical method for designing densimeters with radioactive radiators and ionization chambers with due allowance for the above-mentioned factors.

Below we give the formulas obtained for the purpose of calculating with sufficient accuracy for practical purposes: the ionization current in the chamber

$$i=0{,}145\cdot10^{-7}\cdot2^{-\frac{t}{T}}\,q\alpha q\xi B_1 B_s E_\gamma A\exp\left[-\mu_p d\sqrt{1-\left(\frac{h}{r}\right)^2\sin^2\alpha_m}\right], \tag{1}$$

where μ_n is the linear coefficient of gamma-radiation absorption in the pulp [5] computed from the formula:

$$\mu_p=\frac{\rho_p(\mu_s-\mu_e)+\mu_1\rho_s-\mu_s\rho_e}{\rho_s-\rho_1}; \tag{2}$$

as well as the current changes (Δi) in the chamber for variations ($\Delta\rho_n$) of the pulp density

$$\Delta i=\frac{\Delta\rho_p\, id(\mu_s-\mu_1)\sqrt{1-\left(\frac{h}{r}\right)^2\sin^2\alpha_m}}{\rho_s-\rho_1}; \tag{3}$$

and the value of the fluctuation current

$$\Delta I_{df} = 0{,}0123 \cdot 10^{-10} E_\gamma \eta \sqrt{\frac{qa\varphi\xi B_1 B_s A \exp\left[-\mu_p d \sqrt{1-\left(\frac{h}{r}\right)^2 \sin^2 \alpha_m}\right]}{\tau 2^{\frac{t}{T}}}}; \quad (4)$$

also the activity of a gamma radiator, for the case when the error due to the equipment is negligible as compared with that due to fluctuations, a condition easily attainable in practice. This activity expressed in millicuries is:

$$A = \frac{0{,}848 \cdot 10^{-7} \cdot 2^{\frac{t}{T}} (\rho_s - \rho_e)^2 \exp\left[\mu_p d \sqrt{1-\left(\frac{h}{r}\right)^2 \sin^2 \alpha_m}\right]}{qa\varphi\xi\tau B_1 B_s \left[1-\left(\frac{h}{r}\right)^2 \sin^2 \alpha_m\right] \left[(\delta\rho_p)_{df} \rho_p d (\mu_s - \mu_l)\right]^2} \quad (5)$$

$$\eta = \frac{0{,}00129 D_c \sqrt{1-\left(\frac{2H}{D_c}\right)^2 \sin^2 \alpha_m}}{0{,}5\left(\frac{E_\gamma}{2{,}04} - 1 + \frac{1}{\frac{E_\gamma}{2{,}04}+1}\right)}. \quad (6)$$

In the above formulas $\underline{t}$ is the guaranteed instrument operating time during which the measurement errors do not exceed tolerances; T is the half-life of the gamma radiator; $\underline{q}$ is the number of gamma quanta for one nuclear decay; ξ is the ionization chamber efficiency; B_1B_s are the coefficients allowing for multiple scatter in the liquid and solid components of the pulp; E_γ is the energy of gamma quanta, Mev; A is the activity of the source, mC; ρ_p, ρ_l and ρ_s are the densities of the pulp, water and the solid component respectively; μ_l and μ_s are the linear absorption coefficients of gamma radiations in the liquid and solid components of the pulp; $\underline{d}$ is the internal diameter of the pulp pipeline; $\underline{r}$ is the radius of the pulp pipeline; τ is the measurement time; $(\delta_{\rho_p})_{df}$ is the relative measurement error of the pulp density related to the statistics of radioactive decay; η is the coefficient accounting for the transit of electrons in the ionization chamber, in which Dc is the diameter of the chamber, and the remaining notations in the last and preceding formulas are shown in Fig. 1 which represents the schematic of a radiated beam collimation.

The above formulas can be simplified owing to the fact that some of the quantities given in them have definite values. It has been confirmed both theoretically and experimentally [6] that the most suitable radioactive isotopes for measuring pulp density are Co^{60} ($E\gamma$ = 1,25 Mev, q = 2, T = 5,3 years) and Cs^{137} ($E\gamma$ = 0,662 Mev, q = 0,92, T = 30 years [7]). The efficiency of the ionization chambers which are filled with air at atmospheric pressure is also known [8]. A thin layer of lead over the internal surface of the chamber considerably raises its efficiency as compared with other normally used materials, such as aluminum or brass. For instance, in this case its efficiency for irradiation by gamma quanta of Co^{60} is 1,6% and of Cs^{137} is 2,7%.

It will be seen from Fig. 1 that the choice of angle φ depends on the size of the ionization chamber and the distance between its axis and the gamma radiator. It is inadvisable to make angle α greater than 16°. Our calculations have shown that for an $\alpha > 16°$ the ionization current rises very little with the rest of the parameters remaining constant, but there is a sharp drop in sensitivity – see (1) and (3). This is particularly noticeable with a pulp density exceeding 1,5 g/cm³. The value of $(\delta\rho_p)_{df}$ is determined by the technical properties of the instrument, and D_c, H and $\underline{d}$ are chosen in designing the instrument. The whole design is made for a maximum pulp density.

Coefficients B_l and B_s may be obtained from graphs (Fig. 2) plotted from the data of N. G. Gusev's computation tables [9]. In Fig. 2 the rise factor B is plotted along the X-axis, and the free transit value D along the Y-axis. The latter quantity is dimensionless, since it is determined by the product of the linear attenuation constant of a narrow beam by the thickness of the absorbing material.

The life of the instrument is normally guaranteed by the producing plant for a period of 1-1½ years. From our experience we can guarantee to supply instruments with radioactive isotopes lasting two years. On this basis the coefficient $2^{t/T}$ for Co^{60} is equal to 1.298 and for Cs^{137} to 1.043.

Hence when Co^{60} is used equations (1), (4) and (5) take the following form:

$$I=1{,}248\cdot10^{-10}\,A\varphi B_1 B_s\,\exp\left[-\mu_p d\sqrt{1-\left(\frac{h}{r}\right)^2\sin^2\alpha_m}\right], \tag{7}$$

$$\Delta I_{df}=0{,}437\cdot10^{-12}\,\eta\tau^{-\frac{1}{2}}\sqrt{A\varphi B_1 B_s\,\exp\left[-\mu_p d\sqrt{1-\left(\frac{h}{r}\right)^2\sin^2\alpha_m}\right]}. \tag{8}$$

$$A=\frac{123{,}3\cdot10^{-7}\,(\rho_s-\rho_1)^2\exp\left[\mu_p d\sqrt{1-\left(\frac{h}{r}\right)^2\sin^2\alpha_m}\right]}{\varphi\tau\,B_1 B_s\left[1-\left(\frac{h}{r}\right)^2\sin^2\alpha_m\right]\left[(\delta\rho_p)_{df}\,\rho_n d\,(\mu_s-\mu_1)\right]^2}. \tag{9}$$

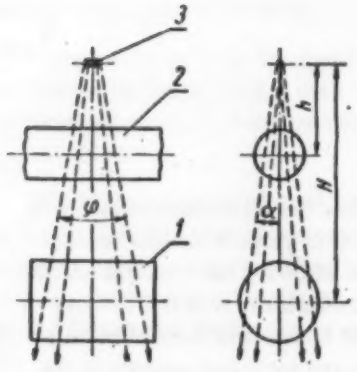

Fig. 1. 1) Ionization chamber; 2) pulp pipeline; 3) radiation source.

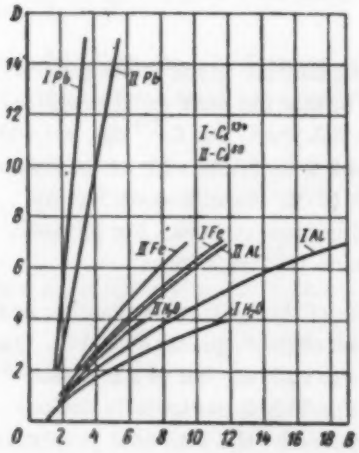

Fig. 2. Relation of the radiation rise factor B to the free transit length D.

If Cs^{137} is used as a gamma radiator, the numerical coefficients in these formulas acquire respectively the following values: $0{,}638\cdot10^{-10}$, $0{,}228\cdot10^{-12}$ and $127{,}5\cdot10^{-7}$.* The coefficients of η for Co^{60} acquire the form:

$$\eta=0{,}011\,D_c\sqrt{1-\left(\frac{2H}{D_c}\right)^2\sin^2\alpha_m} \tag{10}$$

and for Cs^{137} the numerical coefficient in the latter formula is equal to 0.032.

An analysis of (5) shows that the time τ for measuring pulp density must be raised if the activity of the source is lowered. Tests have shown that the choice of τ depends on the duration of transient processes in discharging the graders of the concentration plants, where technological conditions require the determination of the pulp density. Since the duration of these processes in discharging the graders varies from 3 to 5 minutes, we reduced considerably the instrument's speed of operation so that the pointer of the indicating instrument in our model [10] traversed the scale corresponding to a variation in density of 0.5 g/cm³ in 3.5 minutes. In the commercial models of the instrument this time amounts to 45 seconds. The operating time was increased by decreasing the transmission ratio between the balancing motor of the compensational rotating wedge and the remote transmission transducer.

Thus, when pulp density is measured by means of ionization chambers, it is possible to reduce considerably the activity of gamma radiators by increasing the measuring time, and improving certain other parameters, such as the multiple scatter factor, and the efficiency and configuration of ionization chamber irradiation.

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* Appeared in the Russian original as $127\cdot5^{7}$. Presumably the above is what was intended.

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MATERIAL RECEIVED BY THE EDITORIAL BOARD

INTRODUCING NEW MEASURING EQUIPMENT IN THE PLANTS OF THE ZAPOROZH'E REGION

D. M. Sizov

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 57-58,
January, 1961

The Zaporozh'e State Inspection Laboratory (GKL) for measuring equipment is engaged in extensive organizational work in introducing new measuring equipment.

On the recommendation of the GKL the Zaporozh'e Sovnarkhoz (Council of National Economy) has instructed all the heads of industrial plants to compile plans for the prospective introduction of new measuring equipment and to reach an agreement concerning these with the GKL.

The Zaporozh'e GKL distributes working drawings for making various devices which speed up the repair and checking of measuring instruments. According to these drawings, for instance the "Zaporozhstal' "Plant produced a universal device for setting knife-edge bearings in scales, and a device for checking the measuring efforts of a micrometer, and an engineering plant made a device for checking dial hole gauges and lever indicators, the Vorovskii Melitopol' Plant made a device for checking micrometers larger than 100 mm, dial hole gauges and indicators.

In order to acquaint the service inspection workers with production automation, the Zaporozh'e GKL in conjunction with the Central Bureau of Technical Information of the Sovnarkhoz organized through the bureau of permanently functioning courses a seminar in the second quarter of 1960 at which papers were read by scientific workers of institutes.

In the third quarter of 1960 a seminar was organized on the current use of induction electricity meters and their prospective substitution by new electronic systems.

In order to spread the information on new measuring instruments, devices and installations designed by inventors and rationalizers of the region, the Central Bureau of Technical Information of the Sovnarkhoz issued, on the suggestion of the GKL, information leaflets.

The GKL has organized a special display of technical information which includes catalogues of new instruments and literature on measuring equipment.

In order to spread the most up-to-date experience on checking and repairing measuring instruments and on assimilating new improved instruments and devices the GKL issues every quarter a technical information bulletin.

In order to exchange experience in the repair of measuring instruments and their inspection the GKL holds regional conferences and seminars.

The GKL personnel renders direct help to the workers of service inspection agencies in the sphere of automation and mechanization of production, and the replacement of obsolete measuring equipment by new instruments.

Owing to the combined effort of the service inspection workers and the GKL over 300 new measuring instruments have been introduced in the "Zaporozhstal' " Plant. When blast furnace No. 2 was reconstructed, over

100 electronic potentiometers, bridges, flowmeters of the latest design were installed. In the thin sheet-metal shop a photoelectric instrument has been installed for measuring automatically the width of hot-rolled metal. As a result of this, rejects were reduced by 50%, and the workers who measured the width of the strip were made available for other work. The installation of contactless isotope thickness gauges in the tin plate shop sharply reduced the number of rejects and made the work much easier. Automatic control of the cooling metal shrinkage in the stripping workshop furnaces raised the productivity of furnaces by 18-20% and saved 5300 rubles per year. The "Kommunar" Plant introduced six pneumatic length gauges type DP.

The Zaporozh'e oil and butter combine replaced its mercury thermometers in the drying assemblies and measuring hoppers by resistance thermometers and thermocouples with electronic potentiometers. It has also introduced 25 registering manometers and replaced 11 freight scales by batching and dial scales.

Considerable work in introducing production automation has been carried out at the Dneprovsk aluminum plant. As a result of this the production of alumina increased by 28%, 18 persons were made available for other work and a considerable saving was made in caustic, steam and water.

Following the suggestion made by the GKL, the Melitopol' oil extracting plant has introduced flowmeters for measuring its oil and benzene. According to preliminary calculations the saving thus obtained amounts to 500-600 rubles per year.

In the iron alloys plant the operation of all the arc furnaces was made automatic, which improved the operation conditions and made it possible to reduce the number of workers engaged in this operation.

At the "Dneprospetsstal' " Plant the operation of the mill's 280 heating-up ovens was made automatic, and the automatic control of continuous furnaces was modernized. The replacement of a hydraulic by an electrical automatic regulator simplified the control of the assembly, reduced the electric power consumption, improved the efficiency of metal heating, and produced a saving of 400 kg of copper. The total saving amounted to 1800 rubles. Mechanization of the manufacture of quartz tips for immersion thermocouples used in measuring temperatures of molten steel produced a saving of 8900 rubles per year.

In the Zaporozh'e refractory plant automatic measurement of temperatures was introduced by means of sliding contacts in the preparatory and firing stages of a revolving oven, as well as an automatic measurement of the amount of initial hot air supplied by means of an intensifier. The introduction of the new measurement equipment and automation has produced a saving (in nominal fuel) of 26 kg per 1 ton of production, or approximately 82000 rubles per year.

The amount of replacement of obsolete measuring equipment and assimilation of modern measuring instruments in the Zaporozh'e region may be judged from the fact that in the second quarter of 1960 alone four factories received over 600 new measuring instruments. This has enabled the industry of the region to develop production automation and mechanization.

CHECKING TRUCK WEIGHBRIDGES

A. D. Snagovskii

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, p. 58,
January, 1961

The journal "Measurement Techniques" (No. 3, 1960) carried an article by S. I. Gauzner entitled "Method for Checking Truck Weighbridges" in which a method for checking truck weighbridges proposed by I. S. Krever is described.

The above method is simpler and more convenient than those previously used, but the device used in its execution, the aluminum carriage, is rather complicated and difficult to make and therefore cannot be produced

in every place where weighbridges are used. Instead of using this carriage it would be simpler to drill a hole in the beam of the scales and press into it not far from the end graduation a freight-scale knife-edge bearing, which could then be used for suspending on it a scale pan by means of a stirrup.

Editorial note. The measuring instruments' administration of the Committee should suggest to the plants which manufacture truck weighbridges to supply them with the knife-edge bearings as suggested by A. D. Snagovskii.

REPAIRING LOOPS

V. G. Yudochkin

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January, 1961

Various types of loop oscilloscopes comprise the basic equipment used in most of the research work conducted.

Unfortunately, the plants which produce these oscilloscopes do not supply them with even a minimum of spare parts (filaments, mirrors, etc.), which are required for repairing the loops. It is, therefore, very difficult to organize the repair of the loops by the means available at the plants. Their repair in situ is made even more difficult by the replacement of loops with coils.

In order to make the repair of loops in situ possible the manufacturing plants should supply the oscilloscopes with a few spare parts for the loops.

Moreover, convenient replaceable fuses should be developed for the loops (for each type of loop and oscilloscope) and their manufacture should be organized.

ESSAYS AND REVIEWS

ORGANIZATION OF THE RADIO-MEASURING INSTRUMENTS' INSPECTION IN THE CHINESE PEOPLE'S REPUBLIC

L. N. Bryanskii

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 59-60, January, 1961

In recent years the production and application of radio measuring equipment has been developing at an accelerated rate in the Chinese People's Republic (Ch. P. R.), thus making the checking of this equipment a very important problem. At present this problem is being dealt with by the Ministry of Engineering in agreement with the Weights and Measures Administration of the ChPR.

In January and February, 1960, the first All-China Conference on electrical and radio measurements was organized by the two above-mentioned bodies. The conference adopted many important decisions which form the basis for a system of state inspection of radio measuring instruments in the Chinese People's Republic.

It is planned to establish in Peking, Sian, Chengtu, Shanghai and later in other cities regional radio measurement laboratories located at the plants of the Ministry of Engineering. In addition inspection and test laboratories will be set up in all the plants making radio equipment and at certain higher educational establishments. The conference also drew up a list of radio measuring equipment subject to compulsory state testing and approved a temporary regulation on test and inspection groups.

The functions of the main laboratories, particularly the Central Laboratory in Peking, are very wide. They include the supervision of the work of inspection and test laboratories, checking reference radio measuring equipment, making special high-precision measurements, developing new reference radio measuring equipment, compiling specifications, and training personnel.

A special three-story building has been designed for the Central Radio Measurement Laboratory. Workshops will be located in the basement of this building and its flat roof will be used for antennas, the area occupied by the building amounts to 6000 m^2. It will also have a conference hall for the design personnel, a library and a reading room.

Sixteen rooms will have air conditioning and four or five will be completely screened.

It is not planned to construct special buildings for the other regional laboratories located at the establishments of the Ministry of Engineering.

These conditions will be in force for several years, but later the checking of radio measuring instruments as well as of other measures and measuring instruments will be carried out in the laboratories of the Weights and Measures Administration. The construction of buildings for inspection laboratories covering many spheres of measurements has already started in Sian, Chengtu, Chungking, Wuhan, Nanking and Shanghai. In all these laboratories departments covering an area of 1000-2000 m^2 will be allocated for testing electrical and radio measuring instruments.

By the time the construction of these laboratories is completed the Central Radio Measurement Laboratory in Peking will also pass to the Administration of Weights and Measures of the ChPR, and the regional laboratories located at the plants of the Ministry of Engineering will only service the establishments of the Ministry. In order to put this plan into effect, it will be necessary in addition to constructing the buildings, also to carry out at

least two tasks, those of training personnel for radio measurements and supplying test laboratories with the required reference radio measuring equipment.

These problems are receiving due attention. The highly qualified personnel is being recruited in the main from graduates of institutes.

For training the personnel with secondary education courses are being organized at the main laboratories. However, the need for experts still remains acute, and the Administration of Weights and Measures plans to establish in Sian in 1960-1963 a polytechnical institute which will specialize in metrological subjects.

The reference equipment is being purchased in the USSR, Czechoslovakia, GDR, Hungary and other countries, or produced in China mainly from Soviet models.

A system of checking radio measuring instruments is now being set up in the ChPR, but the great attention paid to this question by the Government and the enthusiasm of the laboratory personnel will undoubtedly ensure that the organization of the radio measuring instrument inspection will be completed in the near future.

ADDITIONAL CURRENT TRANSFORMER USED AS A BALANCING INSTRUMENT IN CHECKING ELECTRICITY METERS*

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 60-61
January, 1961

Side by side with reference constant-load electricity meters which are connected through instrument transformers, meters of a lower grade are also used. The errors of these meters must be allowed for in determining the errors of the meter under test. The processing of measurement results under these conditions becomes rather complicated. The supplementary current transformer here described makes it possible to allow for the errors of the reference electricity meter directly during the measurements.

By means of the supplementary transformer (Fig. 1) the current in the series winding of the reference meter 1 is varied with respect to current I in the winding of the meter 2 under test by the amount of ΔI. The value of the ΔI current is set to compensate the error of the reference meter. Current ΔI is produced by the additional transformer whose primary winding takes current I. The additional transformer is supplied with a large number of taps on its secondary winding in order to be able to adjust current ΔI over a wide range. A switch is provided for this purpose in the transformer, and supplied with a current setting of $\Delta I = 0$. The direction of current ΔI is changed either by interchanging the ends of the secondary winding or by using a transformer with two secondary windings (Fig. 2).

The accuracy requirements of the additional transformer are easily met. Transformation ratio inaccuracies constitute a second order error for current I. Moreover, it is possible to make an additional transformer with such a small power consumption that it can be used even with constant-load electricity meters which are connected through a current transformer. By using a core with a high initial permeability it is possible to make a 1 va additional transformer which can be employed over the whole range of currents in normal use. The primary winding of the transformer can be made with a few turns (for instance, 2), so as to keep the number of turns in the secondary winding small as well.

Load B' for the additional transformer is made up by impedance R of the electricity meter winding and currents I and ΔI:

$$B' = R(I+\Delta I)\Delta I = R(I\Delta I + \Delta I^2) \approx RI^2 \frac{\Delta I}{I} = B\frac{\Delta I}{I},$$

* Report of an article by R. Friedl. Fehlerstromwandler also Vergleichsmessgerät zur Fehlerbestimmung bei Zählerprüfungen. Z. für Instrumentenkunde 8, 1960.

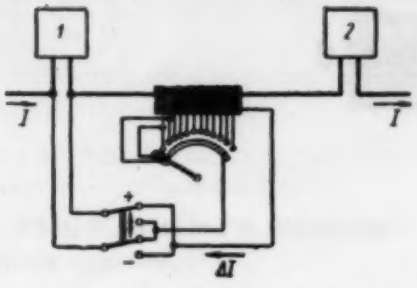


Fig. 1.

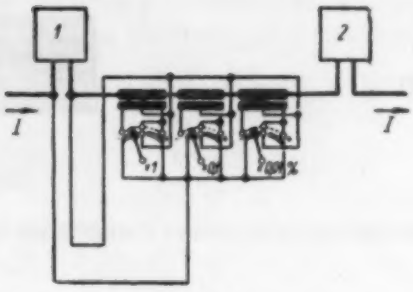


Fig. 2.

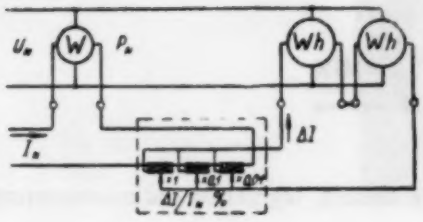


Fig. 3.

where B is the total power in the reference electricity-meter winding.

For instance, when an additional transformer is connected in series with a high-overload electricity meter 10 (50) amp which has a B = 0.1 va, the transformer load B' amounts to 0.005 va for a normal electricity-meter load and $\Delta I/I = 0.05$, and to 0.125 va for a maximum meter load.

Figure 2 shows a circuit for connecting an additional transformer which can compensate the error of a reference electricity meter in the range of ±9.99% in setups of ±0.01%. This device consists of three additional transformers in a decade connection. The error of the additional device in any position of the switch for primary currents of 0.05 to 50 amp does not exceed ±2% of the estimated electricity meter error. This device can also be used for determining the error of the meter under test by a stroboscopic method. In this case the switches of the additional transformers are adjusted to make the speeds of the reference and tested meters equal, which is attained when the stroboscopic pattern becomes stationary. The difference in the speeds of the two meters is determined from the reading of the transformer switches.

Moreover, this device can also be used successfully for combined checking of test racks by means of the previously described method (R. Friedl, Z. für Instrumentenkunde, 65, 1957, p. 188).

This device is convenient for determining the sensitivity of electricity meters. In such a case (Fig. 3) the series windings of the meters under test are connected to the secondary windings of the additional transformers. The nominal current is set by means of a wattmeter. The sensitivity of the meters with respect to the nominal current is determined by the position of the switches in the additional transformers.

Feingeräte TECHNIK

No. 8, August, 1960

Keil. New organizational methods in the sphere of the control, regulation and measurement techniques in industry.

Mutze. Double-beam recording photometer on the basis of a Zeiss high-speed photometer.

Gedler. Position of optical elements in photoelectronic devices.

Instruments for measuring vibrations. Description and photographs of a number of instruments made by the firm Metalwerke, Meirale (Saxony).

Herfurth. Advantages of the MKS system.

Fischer. The use of nomographs in statistical quality control.

Lossman. Mechanized device for graduating and inscribing glass surfaces.

Session of the International Preparatory Committee for the International Conference on Measurement Techniques and Instrument Making, to be held from June 25 to July 1, 1961, in Budapest.

REVUE de METROLOGIE

No. 3, March, 1960

L. Gehant. Indicating and printing devices for automatic weighing instruments.

No. 4, April, 1960

G. Senes. New standards for measuring gas flow by means of a differential manometer flowmeter.

No. 5, May, 1960

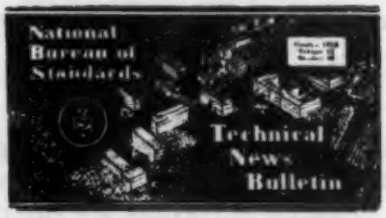
M. Krah. Modern tendencies in measuring oil products. Review of devices for measuring the flow and quantity of oil products.

MICROTECNIC

v. 14, No. 4, 1960

E. Bikel, H. Opitz and N. Weingraber. Investigation of the accuracy of electrical instruments for measuring surface roughness.

N. Weingraber. Measurements of the deviations of details from their ideal geometrical form by means of system E.



No. 8, 1960

Spectroradiometer for luminescent lamps. Designed for calibrating color standards in luminescent lamps.

Description of the NBS laboratories under construction and of their equipment.

INFORMATION

EXHIBITION OF TEST MACHINES AND VIBRATION EQUIPMENT OF THE GERMAN DEMOCRATIC REPUBLIC

S. I. Gauzner

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 62-63,
January, 1961

At the exhibition of test machines and vibration equipment of the GDR held in October, 1960, in Moscow, a number of national establishments exhibited machines and instruments for testing the mechanical properties of metals and materials, balancing equipment and devices, test vibration racks, instruments for measuring and recording oscillations, and regulating instruments.

Among the machines and instruments exhibited by the Werkstofprüfmaschinen Plant (Leipzig) those of the greatest interest included:

1. Reference stationary dynamometers. NBM100 and NBM500 of 100 and 500 ton-wt for checking portable reference dynamometers.

2. A set of instruments for determining the hardness of metals:

Gauge HP250 for Brinell tests at 15.625; 31.25; 62.5; 125; 187 and 250 kg-wt and Rockwell tests at 100 and 1500 kg-wt.

Gauge HPO250 for Brinell tests at 15.625, 31.25, 62.5, 125, 187 and 250 kg-wt and Vickers tests at 5, 10, 15, 20, 30, 40, 50, 60, 100 and 120 kg-wt.

In these instruments the weights are placed in position by push-button control. The instruments are supplied with optical devices which magnify the indentations 70 or 140 times and produce their images on a frosted screen incorporated in the instrument. The indentation is measured by means of a calibrated rule and a micrometer device in the range of 0 to 1.6 mm with an error of 0.001 mm.

Gauge HPO3000 for determining hardness by Brinell tests in the range of 250, 500, 750, 1000 and 3000 kg-wt. The weights are placed in position by means of a control lever. The instrument is supplied with an optical measuring device with a magnification of 25 and an eyepiece micrometer calibrated in 0.01 mm.

Gauge HPA for automatic sorting of details with respect to hardness into three groups. This instrument is based on instrument HP250 with a device for setting the required hardness and tolerances. The number of details is recorded on three meters. The instrument can operate with a conveyor or any device for feeding the details.

Gauge HPO10, a portable instrument for determining the hardness of large details by the Vickers tests for loads of 5 and 10 kg-wt. The instrument is equipped with an optical device for measuring the imprints with a magnification of 100 diameters.

3. Universal three-scale machines in five versions, ZD4, ZD10, ZD20, ZD40 and ZD100, for testing under static conditions samples of materials for tensile strength, compression and bending for maximum loads of 4, 10, 20, 40 and 100 ton-wt respectively. Their measurement error in the range of 10-100% of the maximum load does not exceed ±1% of the measured value, and below 10% it does not exceed the minimum calibration of the corresponding scale. The machines are supplied with a regulating multipiston pump, a constant load hydraulic regulator with an error of ±2%, an automatic loading rate regulator and a recording instrument for plotting the loading diagram.

For testing samples under varying (pulsating) unidirectional loads these machines, with the exception of ZD4, are supplied with a pulsator and a second distribution board and a control desk. They are made in four versions: ZD10Pu, ZD20Pu, ZD40Pu and ZD100Pu for unidirectional pulsating-load ranges of 1-6, 1-11, 1-22, and 5-55 ton-wt respectively, and a pulsating frequency of 500-1500 load/min for the first three models and 250-7500 load/min for the ZD100Pu model.

The machine and the pulsator should be installed on a foundation which does not transmit to the building the vibrations produced by the pulsating loads.

4. Vertical machines type ZDM 600/1200 Pu for testing metals under static conditions for tension at loads up to 600 ton-wt, compression at loads up to 1200 ton-wt and pulsating unidirectional loads for tension from 50 to 300 ton-wt and compression from 50 to 600 ton-wt.

5. Vertical machines ZD200Pu and ZDM300/600Pu for tensile, compression and bending tests with a pulsator for producing unidirectional and reversing loads. Maximum static tensile loads of 200 and 300 ton-wt, and compressive and bending loads of 250 and 600 ton-wt; the maximum values of reversible loads are ± 100 and ± 150 ton-wt, the error of measurement is ± 1% of the measured value.

6. An equipment for testing building structures and their details.

7. Horizontal machines for testing anchor and traction chains, cables and ropes for fracture. Their maximum loads are: 100 ton-wt (ZML-100) and 500 ton-wt (ZML-500), the distance between grips is variable, up to 27.5 m; the measurement error is ±3% of the applied effort.

8. Horizontal ZDML-400 machines for testing samples and details up to 10 m long for tension and compression up to 400 ton-wt and for bending up to 100 ton-wt. Their measurement error is ±1% of the applied effort.

9. Various presses and machines for testing building materials, springs, rails, as well as sheet materials for large extensions.

10. Machines for testing samples for creep and relaxation at temperatures of 300 to 900°C.

11. Machines M4, M10, M20 and M40 for testing samples of nonmetallic materials for rupture and elongation by means of automatic dynamometers. The tensile force acting on the load lever twists a steel measuring rod and at the same time causes the capacity of a differential capacitor to be measured; the potential difference thus produced is amplified and transmitted to the control winding of a Ferraris motor (with split poles) which produces a reactive moment counteracting the moment produced by the tensile force. The servomotor operates the load indicator pointer, the recording instrument and the stored energy meter, which automatically integrates the area under the load versus deformation curve.

12. Swinging ram impact machines PSW3000 and PSW500 for testing metals for impact bending and determining the work of the impact, its force and the deformation. The first machine has two exchangeable rams with a stored energy of 15 and 30 kg-wt · cm, and the stored energy in the second is equal to 0.6, 1.5, 3 and 5 kg-wt · cm. The impact machines are provided with piezo-electric force transducers, whose electrostatic charge is directly proportional to the force of the impact, and a photoelectric transducer of deformations. The voltages from both transducers are amplified and fed to an oscilloscope supplied with a camera which takes photographs of impact bend diagrams.

The Thüringer Industriewerk Plant (Rauenstein) exhibited the following equipment:

1. Machines FMGb-250, FMGb-500 and FMGb-1000 for testing the extension and rupture of cloth, canvas and other textile materials at maximum loads of 250, 500 and 1000 kg-wt respectively.

2. Machines CMG-250 and CMG-500 for testing the extension and rupture of rod and ring samples of rubber at maximum loads of 250 and 500 kg-wt respectively.

3. Machines ZP4, ZP10, ZP20 and ZP40 for testing the stretching of paper and cardboard at maximum loads of 4, 10, 20 and 40 kg-wt respectively. The machines are equipped with a rule for measuring elongation, a recording instrument for plotting load versus elongation diagrams, and an integrator for measuring the stored energy.

All the above machines of this plant have a measurement error of ± 1% of the applied force.

The Geräte und Reglerwerke Plant manufactures the following equipment:

1. Balancing equipment for finding and eliminating static and dynamic unbalance in automobile wheels. The maximum measured unbalance is 8000 g-wt·cm.

2. Balancing equipment AM10 for dynamic balancing of details in which the oscillations due to unbalance are transmitted to bearings equipped with electrical transducers which convert the mechanical vibrations into electrical oscillations displayed on a screen.

The unbalance of a detail is characterized by the radius of the luminous circle which moves on the screen calibrated in polar coordinates with a circular scale. This equipment is designed to balance details weighing 0.2-10 kg with diameters up to 320 mm and a maximum moment of inertia of 400 g-wt·cm·sec^2.

3. Balancing equipment for dynamic balancing of details operating on the principle of a double-pendulum resonance with an incorporated drive. The models now being produced AM50, AM500 and AM2000 cover a balancing range for details weighing between 5 and 2000 kg with a moment of inertia up to 5000 g-wt. cm.

4. Vibration racks with an electrical motor drive for testing instruments weighing up to 35 kg for shaking are produced in two versions covering frequencies of 20-80 cps and 80-300 cps, and amplitudes of 0.05-2.5 mm and 0.02-1.5 mm respectively.

5. Vibration racks with an electrodynamic drive in which the plate with the tested object fixed to it is vibrated by means of a coil which oscillates in a field of an electromagnet supplied with a direct current; an alternating current passes through the coil winding. The test racks are produced in two versions, for details weighing up to 5 kg and a frequency of 20-600 cps, and for details weighing up to 15 kg and a frequency of 50-1000 cps.

6. Three-component vibration racks for testing instruments and grain, powdered and semi-oxidized materials with vibrations in one, two or three directions, driven by means of an electrical motor. The frequency range is 25-220 cps, amplitude range of 0-3 mm, and a maximum weight of the tested object is 30 kg.

7. Racks for testing instruments for shocks and shocklike vibrations at the rate of 20-80 impacts per min; the maximum weight of the tested object is 50 kg.

8. Various hydraulic, electrical and pneumatic regulators for automatic control of various quantities such as pressure, amount, temperature, humidity, etc.

The Metalwerker Plant manufactures various instruments for measuring mechanical vibrations:

1. Torsiographs, which serve to register twisting oscillations, the critical number of turns, angular deviations, degrees of nonuniformity in the rotation of shafts and rotating parts of machines.

2. Vibrographs for measuring and recording oscillations and vibrations in machines, buildings, foundations, bridges, etc., in horizontal, vertical and diagonal directions.

3. Tachographs for registering variations in the number of revolutions in starting and stopping machines, vibrations in regulators, machines operating parallel to each other, etc.

The above list does not cover all the machines and instruments produced by the national establishments of the GDR, but it gives an idea of the considerable development in the GDR of the industry producing test and vibration machines and instruments. The great experience accumulated by these establishments should be studied.

The dynamometer with a twisting rod is of particular interest since it has considerable advantages as compared with the ram-type dynamometer.

It should also be noted that the testing machines (according to the data of the Werkstofprüfmaschinen) have an error of 1% starting at 10% of the smallest range.

INSTRUMENTS FOR LINEAR AND OPTICAL MEASUREMENTS AT THE EXHIBITION OF THE FEDERAL GERMAN REPUBLIC

L. Ya. Kraskov

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, pp. 63-64, January, 1961

An exhibition of laboratory and commercial instruments of the Federal German Republic firms was held at the premises of the Moscow Polytechnical Museum from November 10 to 24, 1960.

The main attention at the exhibition was paid to showing the latest medical equipment. Instruments for linear and optical measurements were exhibited by the firm Ernst Leitz. Among the instruments shown by this firm the following were of the greatest interest.

The ultra projection meter designed for measuring linear dimensions by a comparison method, and in the first instance for checking block gauges. With calibrations of 0.1 μ the instrument has a measuring range along the scale of $\pm 25\,\mu$ and a total range of 200 mm. The readings are taken off a frosted glass screen on which the scale is reproduced optically. The instrument is controlled for temperature and supplied with a thermometer for checking its temperature during testing. The measuring effort can be controlled in the limits of 50 to 200 g-wt. The measurement error amounts to $\pm 0.03\,\mu$.

A vertical height gauge for absolute linear measurements up to 100 mm and comparative linear measurements up to 200 mm. The instrument has a glass scale 100 mm long with graduations of 1 mm, whose image is projected by an optical system onto a frosted glass screen. The scale is read by means of an optical micrometer with calibrations of 1 μ. The oil damper provides a smooth movement to the tail spindle and an adjustment of the measuring effort. The measurement error of the instrument is $\pm(1 + L/100)\,\mu$, where L is the measured length in mm.

The new model of the large measuring microscope is supplied with a binocular eyepiece micrometer. Two interchangeable objectives 1:1 and 5:1 together with the built-in microscope with a variable magnification of 10, 20 and 30 diameters make it possible to operate with six different magnifications from 10 to 150 diameters and a field of vision of 20 to 1.3 mm respectively. Instead of the usual table with micrometer screws this measuring microscope has a coordinate table with an optical read-out device and a displacement range of 200x 75 mm. The image of the glass scale with its 1 mm calibrations is projected by means of an optical system onto a frosted glass screen. The position of the slide can be determined on the frosted glass screen by means of an optical micrometer with an error not exceeding 5 μ.

A table projector provides images of details on a screen with a magnification of 10, 20 and 50 diameters. The instrument can work both in transmitted and reflected light. The details placed on the instrument's coordinate table are measured by means of micrometer screws.

An infrared spectrograph provides analysis of chemical compounds by means of their infrared spectral absorption. The instrument operates in the near infrared range on wavelengths of 1 to 23 μ. The instrument is completely automatic and provides in a few minutes the infrared spectrum of the tested substance.

In addition to the above instruments the firm of Ernst Leitz exhibited a metallographic microscope, a micro hardness gauge, optical dividing heads, a polarization microscope, a microscope for measuring nuclear particle tracks, etc

COMMITTEE OF STANDARDS, MEASURES, AND MEASURING INSTRUMENTS

CHANGES IN THE CURRENT SPECIFICATION FOR CHECKING MEASURES AND MEASURING INSTRUMENTS

Translated from Izmeritel'naya Tekhnika, 1961, No. 1, p. 64,
January, 1961

The Committee of Standards, Measures and Measuring Instruments has made effective from January 1, 1961, the changes introduced in the specification 114-56 for checking optical height gauges.

Sections 7, 10, 14 and 19 of the instruction have been changed. Paragraph 7k now reads: "When the eyepiece is adjusted to the sharp definition of graduations and figures on the eyepiece scale, the image of the millimeter scale should be observed with the same sharpness of definition, and the parallax of the scale must not exceed ± 0.5 diopters." Paragraph 10a has been replaced by the following text: "A deviation from the plane of the table not exceeding 0.001 mm on the concave side is allowed over the whole length of the table." The last paragraph of section 14b now reads: "The maximum difference in readings obtained for the four positions of the gauge must not exceed 0.007 mm for a point diameter for 8 mm." The formula in section 19a is changed to: "$\pm 0.0015 + \alpha/100000$ mm (without applying a scale correction)."

In view of the alteration of taximeters to new rates of charges the Committee has issued an instruction to continue checking these instruments, until such time as a new specification is approved, according to the existing specification No. 145, with the following changes. In addition to the checking operations specified in instruction 145, it is also necessary to check:

1. The engaging mechanism. The sum of 10 kopeks must appear on the face of the meter when its handle is turned from "engaged" to "free" for taximeters types TA-49A and TA-49 and when turned from position "free" to position "engaged" for taximeters types TA-49A1 and TA-49B1.

2. For taximeters type TA-49 and TA-49A the counter "landing" should be checked and for taximeters TA-49A1 and TA-49B1 the counter "pay" which registers the total sum due should be checked. In checking the counter "pay" the previously established requirements remain in force.

Taximeters TA-49, TA-49B, TA-49A1, TA-49A, TA-49B1 and TA-49C1 should be accepted for testing. Taximeters T-9, which have not passed state testing, but are in current use, are considered to be experimental models not subject to state testing.

Soviet Journals Available in Cover-to-Cover Translation

ABBREVIATION	RUSSIAN TITLE	TITLE OF TRANSLATION	PUBLISHER	TRANSLATION BEGAN Vol.	Issue	Year
AÉ	Atomnaya énergiya	Soviet Journal of Atomic Energy	Consultants Bureau	1	1	1956
Akust. zh.	Akusticheskii zhurnal	Soviet Physics – Acoustics	American Institute of Physics	1	1	1955
	Antibiotiki	Antibiotics	Consultants Bureau	4	1	1959
Astr(on). zh(urn).	Astronomicheskii zhurnal	Soviet Astronomy–AJ	American Institute of Physics	34	1	1957
Avto(mat). svarka	Avtomaticheskaya svarka	Automatic Welding	British Welding Research Association (London)		1	1959
	Avtomatika i Telemekhanika	Automation and Remote Control	Instrument Society of America	27	1	1956
	Biofizika	Biophysics	National Institutes of Health*		1	1957
	Biokhimiya	Biochemistry	Consultants Bureau	21	1	1956
Byull. éksp(erim). biol. i med.	Byulleten' éksperimental'noi biologii i meditsiny	Bulletin of Experimental Biology and Medicine	Consultants Bureau	41	1	1959
DAN (SSSR) / Dokl(ady) AN SSSR	Doklady Akademii Nauk SSSR	The translation of this journal is published in sections, as follows:				
		Doklady Biochemistry Section	American Institute of Biological Sciences	106	1	1956
		Doklady Biological Sciences Sections (Includes: Anatomy, biophysics, cytology, ecology, embryology, endocrinology, evolutionary morphology, genetics, histology, hydrobiology microbiology, morphology, parasitology, physiology, zoology sections)	American Institute of Biological Sciences	112	1	1957
		Doklady Botanical Sciences Sections (Includes: Botany, phytopathology, plant anatomy, plant ecology, plant embryology, plant physiology, plant morphology sections)	American Institute of Biological Sciences	112	1	1957
		Proceedings of the Academy of Sciences of the USSR, Section: Chemical Technology	Consultants Bureau	106	1	1956
		Proceedings of the Academy of Sciences of the USSR, Section: Chemistry	Consultants Bureau	106	1	1956
		Proceedings of the Academy of Sciences of the USSR, Section: Physical Chemistry	Consultants Bureau	112	1	1957
		Doklady Earth Sciences Sections (Includes: Geochemistry, geology, geophysics, hydrogeology, mineralogy, paleontology, petrography, permafrost sections)	American Geological Institute	124	1	1959
		Proceedings of the Academy of Sciences of the USSR, Section: Geochemistry	Consultants Bureau	106-123	1 6	1957-1958
		Proceedings of the Academy of Sciences of the USSR, Sections: Geology	Consultants Bureau	106-123	1 6	1957-1958
		Doklady Soviet Mathematics	The American Mathematics Society	131	1	1961
		Soviet Physics–Doklady (Includes: Aerodynamics, astronomy, crystallography, cybernetics and control theory, electrical engineering, energetics, fluid mechanics, heat engineering, hydraulics, mathematical physics, mechanics, physics, technical physics, theory of elasticity sections)	American Institute of Physics	106	1	1956
		Proceedings of the Academy of Sciences of the USSR, Applied Physics Sections (does not include mathematical physics or physics sections)	Consultants Bureau	106-117	1	1956-1957
Derevoobrabat. prom-st'.	Derevoobrabatyvayushchaya promyshlennost'	Wood Processing Industry	Timber Development Association (London)		9	1959
	Élecktrosvyaz	Telecommunications	Massachusetts Institute of Technology*		1	1957
Éntom(ol). oboz(renie)	Éntomologicheskoe obozrenie	Entomological Review	American Institute of Biological Sciences	38	1	1959
Farmakol. (i) toksikol(ogiya)	Farmakologiya i toksikologiya	Pharmacology and Toxicology	Consultants Bureau	20	1	1957
FMM	Fizika metallov i metallovedenie	Physics of Metals and Metallography	Acta Metallurgica*	5	1	1957
Fiziol. zhurn. SSSR (im. Sechenova)	Fiziologicheskii zhurnal im. I. M. Sechenova	Sechenov Physiological Journal USSR	National Institutes of Health*		1	1957
Fiziol(ogiya) rast.	Fiziologiya rastenii	Plant Physiology	American Institute of Biological Sciences	4	1	1957
	Geokhimiya	Geochemistry	The Geochemical Society		1	1958
FTT	Fizika tverdogo tela	Soviet Physics–Solid State	American Institute of Physics	1	1	1959
Izmerit. tekh(nika)	Izmeritel'naya tekhnika	Measurement Techniques	Instrument Society of America		1	1959
Izv. AN SSSR, O(td). Kh(im). N(auk)	Izvestiya Akademii Nauk SSSR: Otdelenie khimicheskikh nauk	Bulletin of the Academy of Sciences of the USSR: Division of Chemical Sciences	Consultants Bureau		1	1952

Life Sciences

Chemical Sciences

Earth Sciences

Mathematics

Physics

continued

Izv. AN SSSR, O(td). T(ekhn). N(auk): Met(all). i top.	(see Met. i top.)					
Izv. AN SSSR Ser. fiz(ich).	Izvestiya Akademii Nauk SSSR: Seriya fizicheskaya	Bulletin of the Academy of Sciences of the USSR: Physical Series	Columbia Technical Translations		1	1954
Izv. AN SSSR Ser. geofiz.	Izvestiya Akademii Nauk SSSR: Seriya geofizicheskaya	Bulletin (Izvestiya) of the Academy of Sciences USSR: Geophysics Series	American Geophysical Union		1	1954
Izv. AN SSSR Ser. geol.	Izvestiya Akademii Nauk SSSR: Seriya geologicheskaya	Izvestiya of the Academy of Sciences of the USSR: Geologic Series	American Geological Institute		1	1958
Kauch. i rez.	Kauchuk i rezina	Soviet Rubber Technology	Research Association of British Rubber Manufacturers	18	1	1959
	Kinetika i kataliz	Kinetics and Catalysis	Consultants Bureau	1	3	1960
	Koks i khimiya	Coke and Chemistry USSR	Coal Tar Research Association (Leeds, England)		1	1958
Kolloidn. zh(urn).	Kolloidnyi zhurnal	Colloid Journal	Consultants Bureau	14	1	1952
	Kristallografiya	Soviet Physics – Crystallography	American Institute of Physics	2	1	1957
Metalov. i term. obrabot. metal.	Metallovedenie i termicheskaya obrabotka metallov	Metal Science and Heat Treatment of Metals	Acta Metallurgica	6	1	1958
	Metallurg	Metallurgist	Acta Metallurgica		1	1957
Met. i top.	Metallurgiya i topliva	Russian Metallurgy and Fuels	Eagle Technical Publications		1	1960
Mikrobiol.	Mikrobiologiya	Microbiology	American Institute of Biological Sciences	26	1	1957
OS	Optika i spektroskopiya	Optics and Spectroscopy	American Institute of Physics		6	1959
	Pochvovedenie	Soviet Soil Science	American Institute of Biological Sciences		1	1958
	Priborostroenie	Instrument Construction	British Scientific Instrument Research Association		1	1959
Pribory i tekhn. éks(perimenta)	Pribory i tekhnika éksperimenta	Instruments and Experimental Techniques	Instrument Society of America		1	1957
Prikl. matem. i mekh.	Prikladnaya matematika i mekhanika	Applied Mathematics and Mechanics	American Society of Mechanical Engineers		1	1958
PTÉ	(see Pribory i tekhn. éks.)					
	Problemy Severa	Problems of the North	National Research Council of Canada			
Radiotekh.	Radiotekhnika	Radio Engineering	Massachusetts Institute of Technology*	12	1	1957
Radiotekh. i élektronika	Radiotekhnika i élektronika	Radio Engineering and Electronics	Massachusetts Institute of Technology*	2	1	1957
	Stanki i instrument	Machines and Tooling	Production Engineering Research Assoc.		1	1959
	Stal'	Stal (In English)	Iron and Steel Institute		1	1959
Stek. i keram.	Steklo i keramika	Glass and Ceramics	Consultants Bureau	13	1	1956
Svaroch. proiz-vo	Svarochnoe proizvodstvo	Welding Production	British Welding Research Association		4	1959
Teor. veroyat. i prim.	Teoriya veroyatnostei i ee primenenie	Theory of Probability and Its Applications	Society for Industrial and Applied Mathematics		1	1956
Tsvet. Metally	Tsvetnye metally	Nonferrous Metals	Primary Sources		1	1960
UFN	Uspekhi fizicheskikh Nauk	Soviet Physics – Uspekhi (partial translation)	American Institute of Physics	66	1	1958
UKh	Uspekhi khimii	Russian Chemical Reviews	The Chemical Society (London)		1	1960
UMN	Uspekhi matematicheskikh nauk	Russian Mathematical Surveys	London Mathematical Society	15	1	1960
Usp. fiz. nauk	(see UFN)					
Usp. khim(ii)	(see UKh)					
Usp. matem. nauk	(see UMN)					
Usp. sovr. biol.	Uspekhi sovremennoi biologii	Russian Review of Biology	Oliver and Boyd		48	1959
Vest. mashinostroeniya	Vestnik mashinostroeniya	Russian Engineering Journal	Production Engineering Research Assoc.		4	1959
Vop. gem. i per. krovi	Voprosy gematologii i perelivaniya krovi	Problems of Hematology and Blood Transfusion	National Institutes of Health*		1	1957
Vop. onk.	Voprosy onkologii	Problems of Oncology	National Institutes of Health*		1	1957
Vop. virusol.	Voprosy virusologii	Problems of Virology	National Institutes of Health*		1	1957
Zav(odsk). lab(oratoriya)	Zavodskaya laboratoriya	Industrial Laboratory	Instrument Society of America	25	1	1959
ZhAKh Zh. anal(it). khimii	Zhurnal analiticheskoi khimii	Journal of Analytical Chemistry USSR	Consultants Bureau	7	1	1952
ZhETF Zh. éksperim. i teor. fiz.	Zhurnal éksperimental'noi i theoreticheskoi fiziki	Soviet Physics–JETP	American Institute of Physics	28	1	1955
ZhFKh Zh. fiz. khimii	Zhurnal fizicheskoi khimii	Russian Journal of Physical Chemistry	The Chemical Society (London)		7	1959
ZhMÉI Zh(urn). mikrobiol. épidemiol. i immunobiol.	Zhurnal mikrobiologii, épidemiologii i immunobiologii	Journal of Microbiology, Epidemiology and Immunobiology	National Institutes of Health*		1	1957
ZhNKh Zh(urn). neorgan(ich). khim(ii)	Zhurnal neorganicheskoi khimii	The Russian Journal of Inorganic Chemistry	The Chemical Society (London)		1	1959
ZhOKh Zh(urn). obshch(ei) khimii	Zhurnal obshchei khimii	Journal of General Chemistry USSR	Consultants Bureau	19	1	1949
ZhPKh Zh(urn). prikl. khimii	Zhurnal prikladnoi khimii	Journal of Applied Chemistry USSR	Consultants Bureau	23	1	1950
ZhSKh Zh(urn). strukt. khimii	Zhurnal strukturnoi khimii	Journal of Structural Chemistry	Consultants Bureau	1	1	1960
ZhTF Zh(urn). tekhn. fiz.	Zhurnal teknicheskoi fiziki	Soviet Physics–Technical Physics	American Institute of Physics	26	1	1956
Zh(urn). vyssh. nervn. deyat. (im. Pavlova)	Zhurnal vysshei nervnoi deyatel'nosti (im. I. P. Pavlova)	Pavlov Journal of Higher Nervous Activity	National Institutes of Health*		1	1958

*Sponsoring organization. Translation through 1960 issues is a publication of Pergamon Press.

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SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET TECHNICAL PERIODICALS

AN SSSR	*Academy of Sciences, USSR*
FIAN	*Physics Institute, Academy of Sciences USSR*
GITI	*State Scientific and Technical Press*
GITTL	*State Press for Technical and Theoretical Literature*
GOI	*State Optical Institute*
GONTI	*State United Scientific and Technical Press*
Gosénergoizdat	*State Power Press*
Gosfizkhimizdat	*State Physical Chemistry Press*
Goskhimizdat	*State Chemistry Press*
GOST	*All-Union State Standard*
Gostekhizdat	*State Technical Press*
GTTI	*State Technical and Theoretical Press*
IAT	*Institute of Automation and Remote Control*
IF KhI	*Institute of Physical Chemistry Research*
IFP	*Institute of Physical Problems*
IL	*Foreign Literature Press*
IPF	*Institute of Applied Physics*
IPM	*Institute of Applied Mathematics*
IREA	*Institute of Chemical Reagents*
ISN (Izd. Sov. Nauk)	*Soviet Science Press*
IYap	*Institute of Nuclear Studies*
Izd	*Press (publishing house)*
LÉTI	*Leningrad Electrotechnical Institute*
LFTI	*Leningrad Institute of Physics and Technology*
LIM	*Leningrad Institute of Metals*
LITMiO	*Leningrad Institute of Precision Instruments and Optics*
Mashgiz	*State Scientific-Technical Press for Machine Construction Literature*
MGU	*Moscow State University*
Metallurgizdat	*Metallurgy Press*
MOPI	*Moscow Regional Pedagogical Institute*
NIAFIZ	*Scientific Research Association for Physics*
NIFI	*Scientific Research Institute of Physics*
NIIMM	*Scientific Research Institute of Mathematics and Mechanics*
NIKFI	*Scientific Institute of Motion Picture Photography*
NKTM	*People's Commissariat of the Heavy Machinery Industry*
Obrongiz	*State Press of the Defense Industry*
OIYaI	*Joint Institute of Nuclear Studies*
ONTI	*United Scientific and Technical Press*
OTI	*Division of Technical Information*
OTN	*Division of Technical Science*
RIAN	*Radium Institute, Academy of Sciences of the USSR*
SPB	*All-Union Special Planning Office*
Stroiizdat	*Construction Press*
URALFTI	*Ural Institute of Physics and Technology*
TsNIITMASh	*Central Scientific-Research Institute of Technology and Machinery*
VNIIM	*All-Union Scientific Research Institute of Metrology*

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us — *Publisher.*

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